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FRICTION STUDY OF AIRCRAFT TIRE MATERIAL ON CONCRETE

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Boeing Airplane Company



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SUMMARY

A systematic study has been made of the variation of frictional resistance between typical tire-tread material and three concrete surfaces of different roughness at various temperatures and normal pressures. Typical tire-tread specimens were taken from the thickest portion of worn ten-ply tires, and the three concrete test blocks were poured from the same mix but subjected to different surface finishes. Curves are presented of the apparent coefficient of friction as a function of normal pressure.

INTRODUCTION

The friction coefficient plays an important role in determining the time history of the drag load during a landing impact, but the rapid changes in normal pressure and temperature during the wheel spin-up have raised some doubt as to the validity of using static friction data in which no effects of temperature have been considered. In order to obtain some insight into the effect of the high temperature and consequent nearly molten rubber on the friction coefficients, the Boeing Airplane Company conducted some tests to determine the frictional resistance between typical tire-tread material and concrete. Although the results were obtained under conditions considerably different from those encountered in landing and taxiing operations where high skidding velocity may be involved, they are, nevertheless, of interest because of the range of pressure and temperature covered and because they represent an end-point condition in airplane operation.

This work has been made available to the National Advisory Committee for Aeronautics for publication because of its general interest.

TEST APPARATUS

Test Specimen

The rubber specimens tested were 1.75 inches in diameter. They were taken from the thickest portion of the tread of a worn ten-ply B-29 type of nose-wheel tire (see fig. 1). This tire had been in storage, prior to this test, at least 18 months since flight usage. Checks were noted over most of its surface.

Three concrete specimens were used (see fig. 2). The concrete was poured from a mix which was being used to complete a side apron at Boeing Field, Seattle.¹ Each concrete specimen was given a surface finish as follows:

Specimen	Finish
1	Troweled smooth (hereafter referred to as "smooth surface")
2	Surfaced with a two-by-four (hereafter referred to as "semismooth surface")
3	Surfaced with a two-by-four and then broomed (hereafter referred to as "rough surface")

Test Setup

Basically, the test consisted of the application of known vertical loads to the rubber specimen followed by the measurement of the maximum side loads occurring in moving the specimen 1 inch on each of the surfaces.

Two setups were used as follows:

(1) High-normal-, or high-vertical-, load tests: The normal or vertical loads applied to the specimens in these tests covered a range from 50 to 1,100 psi. Vertical loads were applied by a long-stroke 10-ton hydraulic jack in 100-psi increments and side loads, by a 3-ton hydraulic jack. The setup is shown in a sketch (fig. 3) and in a photograph (fig. 4).

¹Concrete (Boeing Type A) ingredients were: Cement, 517 pounds per cubic yard; fine sand, 1,270 pounds per cubic yard; and fine gravel, 2,080 pounds per cubic yard.

(2) Low-normal-, or low-vertical-, load tests: The normal or vertical loads applied to the specimens in these tests covered a range from 25 to 310 psi. Vertical loads were applied by a weight-loading device in 20-psi increments and side loads, by a 3-ton hydraulic jack. The setup is shown in a sketch (fig. 5) and in a photograph (fig. 6).

Heat effects were simulated by slowly heating the concrete surface with an oxyacetylene heating torch. The temperature of the surface was measured immediately prior to and immediately after each load application by a portable thermocouple. The temperature values in this report are the averages of these two readings.

TEST PROCEDURE

The high-normal-load tests were run first. Tests were conducted with the concrete at room temperature (approximately 75° F) and at 300° F. Three complete runs of the normal-force range were made on each surface at each of these temperatures.

The majority of the tests was conducted with the low-normal-load setup. This was due to the fact that the range covered by this setup (25 to 310 psi) more closely simulated present-day tire pressures. The high-normal-load setup was not accurate in this range.

Using the low-normal-load setup, three complete runs were made on each of the smooth and rough surfaces with the concrete at room temperature, 300°, 400°, and 500° F. Three runs each were made on the smooth surface at 600° F and 700° F.

Rubber specimens were changed at each change in temperature. However, each specimen was used repeatedly throughout the temperature increment until worn out. The specimens were considered worn out when further wear would cause the specimen mounting plate to bear upon the concrete surface.

After each load application the rubber specimen and concrete surface were wiped free of rubber particles. In addition, the reheating of the concrete between each of the high-temperature tests helped to remove rubber deposits.

As aircraft tires sometimes leave prints on the runway a full revolution after the initial landing skid mark, an attempt was made to determine the "printing characteristics" of tire rubber at various temperatures. A new, untested specimen was used for each temperature increment and for each run (two runs were made at each temperature). The prints were made as follows:

- (1) At each temperature increment a normal load of 155 psi was applied to a new, untested specimen on the smooth surface.
- (2) The necessary side load to slide the specimen 1 inch was applied.
- (3) Immediately following step (2) the specimen was placed upon a plywood section and a normal load of 155 psi was applied.

RESULTS

Curves of the apparent coefficient of friction versus normal pressure and curves of normal load versus horizontal (or drag) load are shown in figures 7 to 19.

The arithmetical averages of all runs are shown, for comparison purposes, in figures 7 and 8 for the high-normal-load tests (50 to 1,100 psi) and in figures 12 and 13 for the low-normal-load tests (25 to 310 psi).

Prints were made on the plywood section at 300°, 400°, 500°, and 600° F. Referring to the photograph of the plywood section (fig. 20), it can be noted that (1) slight printing began at 400° F, (2) printing increased in intensity as the rubber was heated further, and (3) at 600° F a full print was obtained.

Boeing Airplane Company,
Seattle, Wash., August 10, 1950.

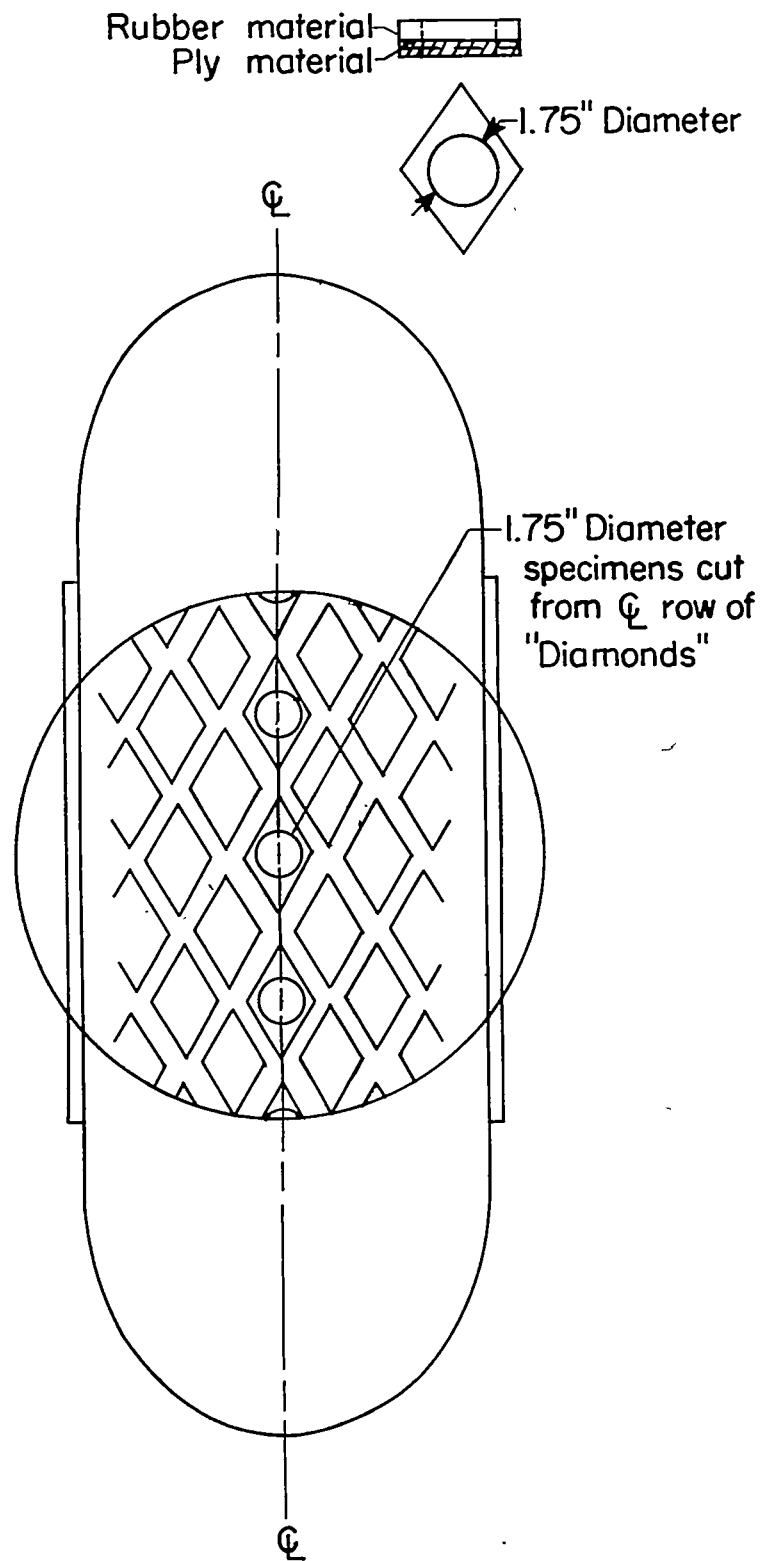


Figure 1.- Rubber test specimens.



L-87977
Figure 2.- Concrete specimens.

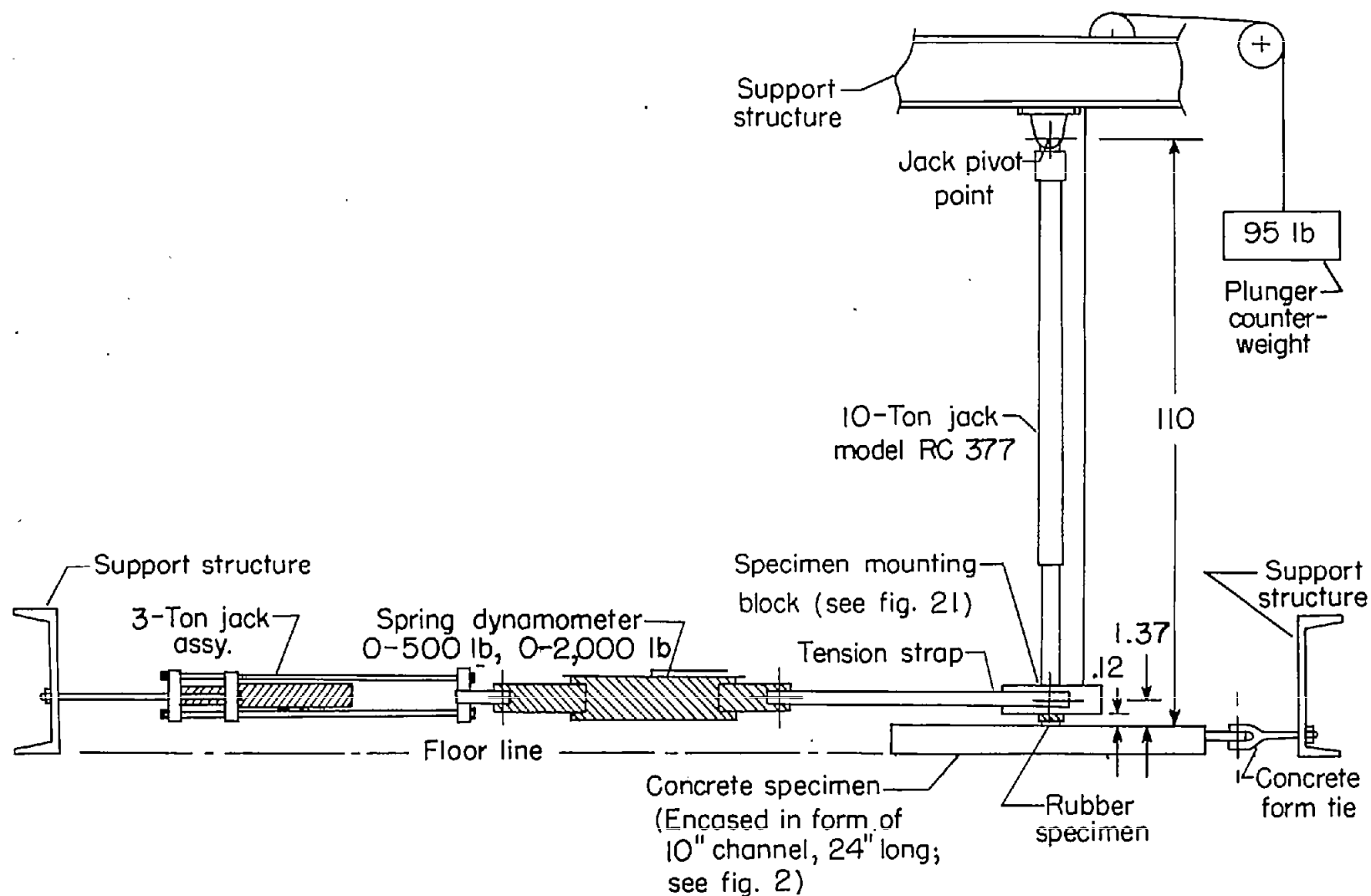


Figure 3.- High-normal-load test setup. Complete setup shown in figure 4.

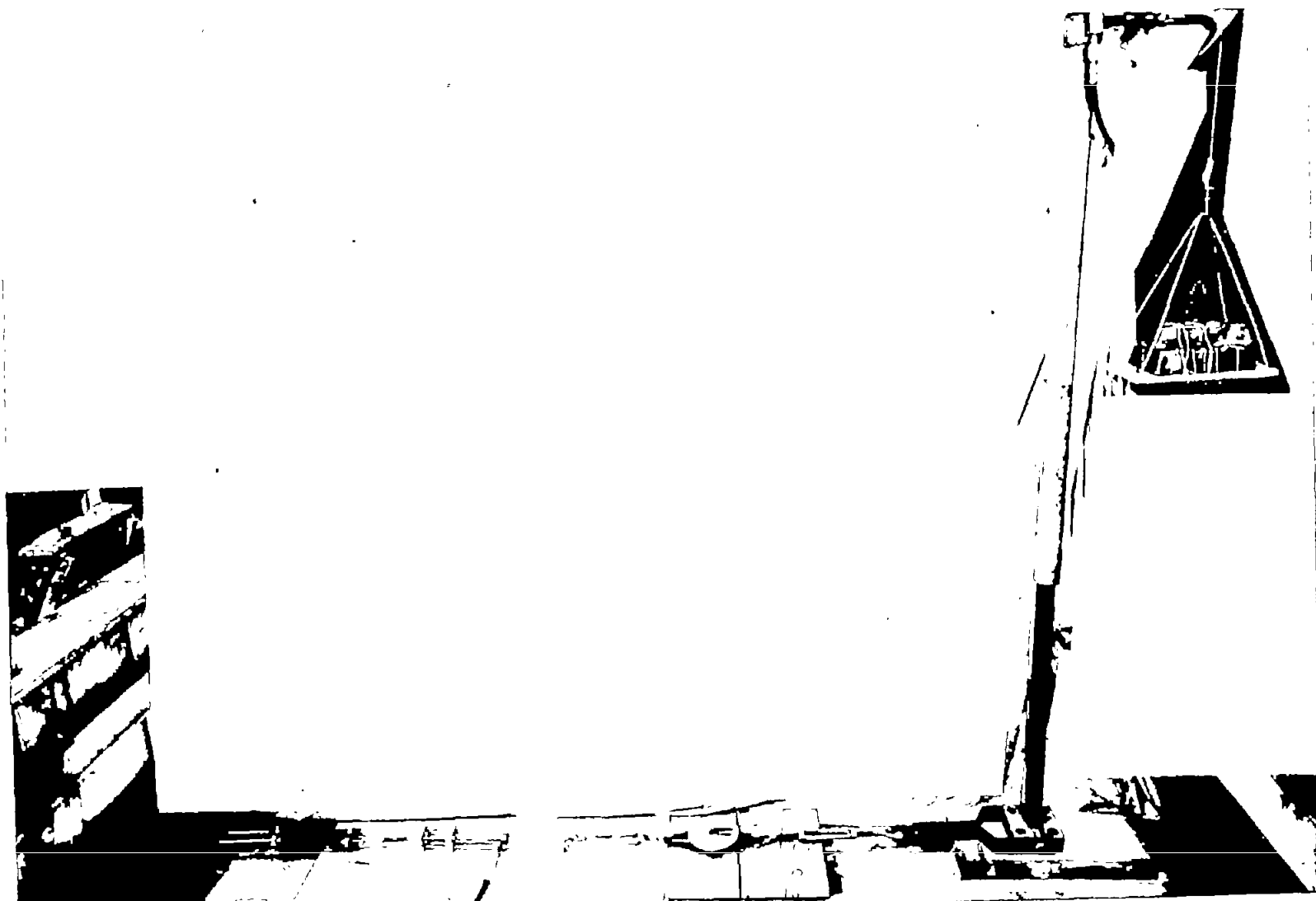


Figure 4.- High-normal-load (50 to 1,100 psi) setup. L-87978

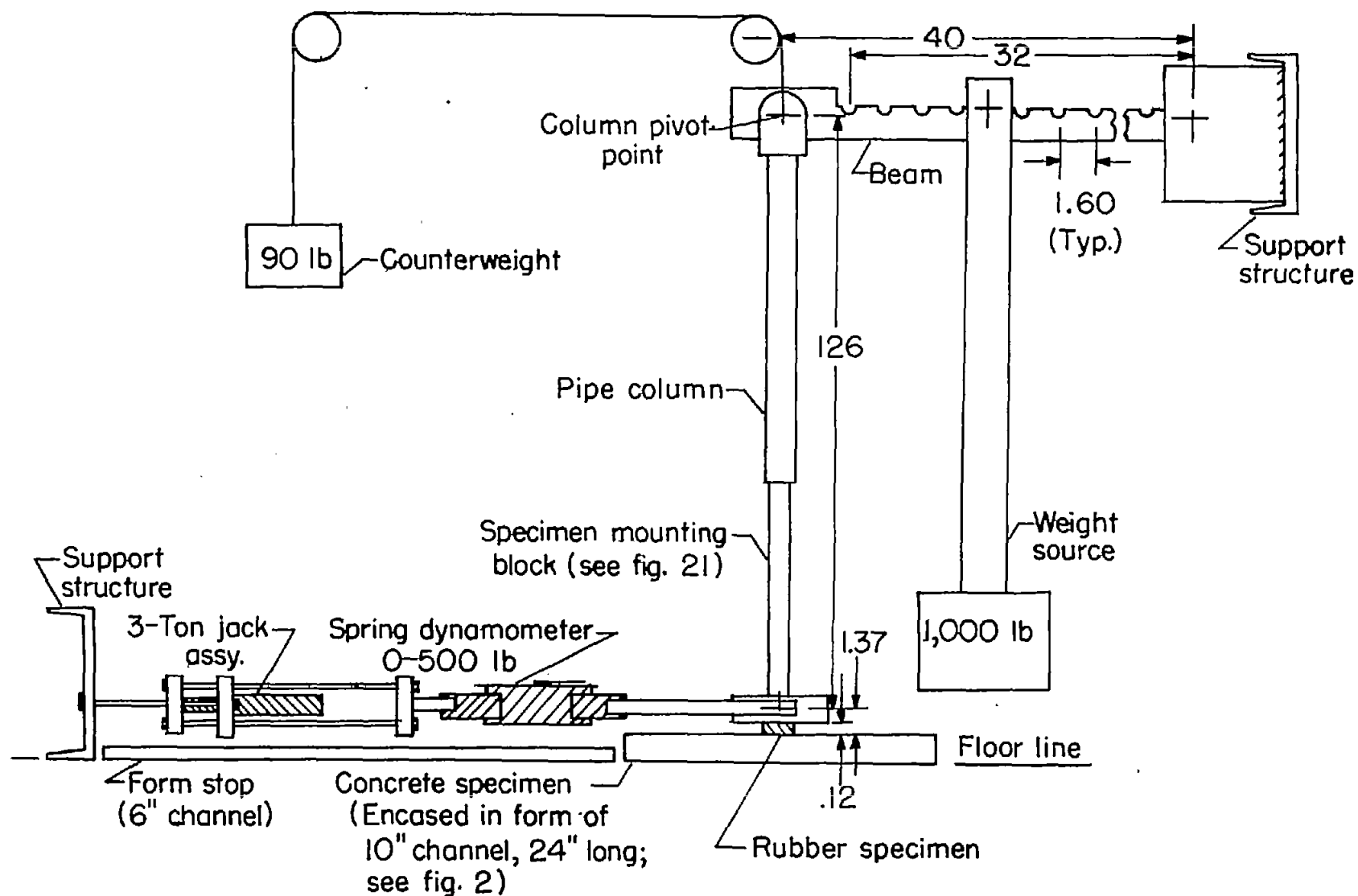


Figure 5.- Low-normal-load test setup. Complete setup shown in figure 6.

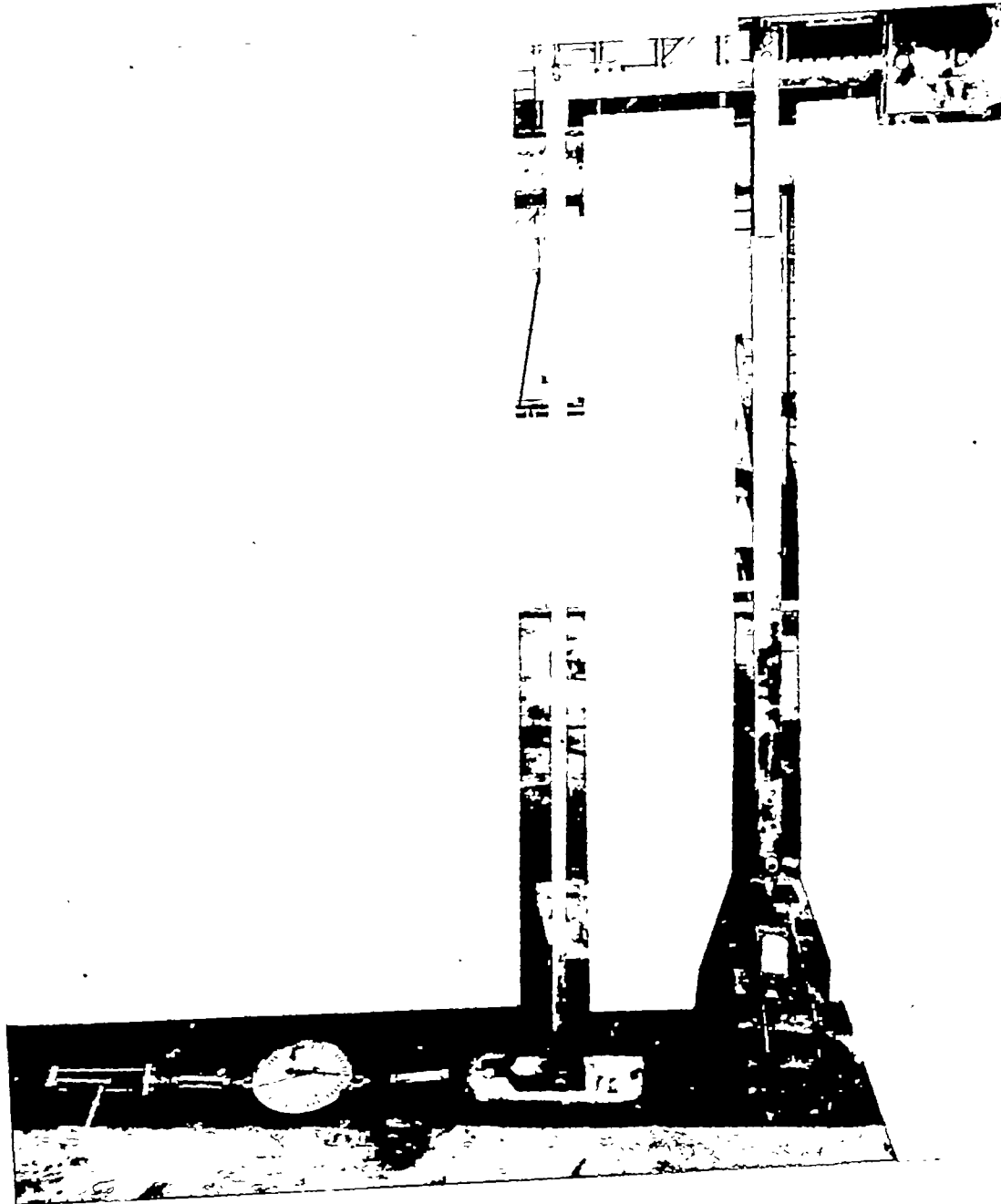


Figure 6.- Low-normal-load (25 to 310 psi) setup. L-87979

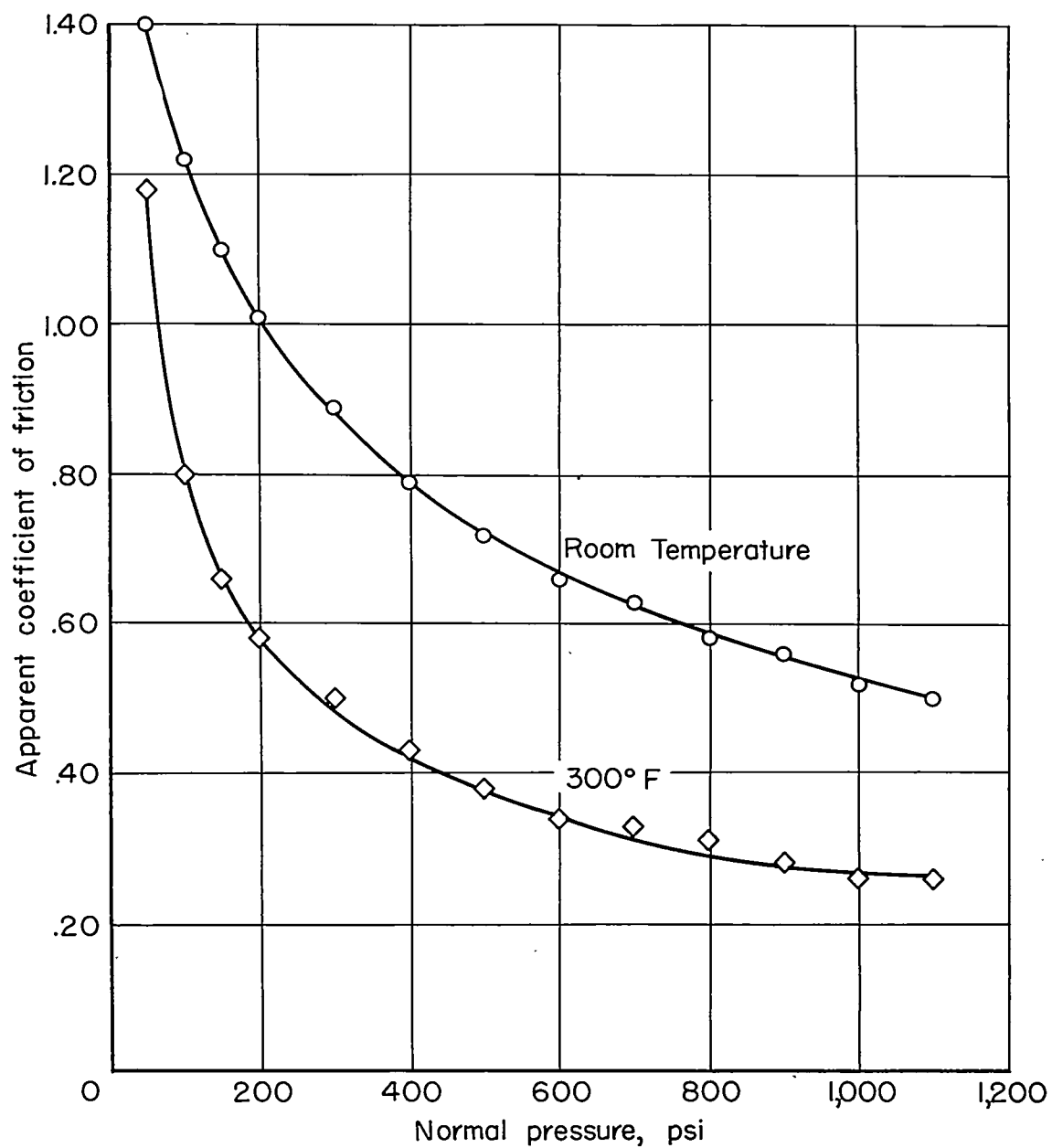


Figure 7.- Apparent coefficient of friction versus normal pressure for high-normal-load tests. Averaged results for all surfaces.

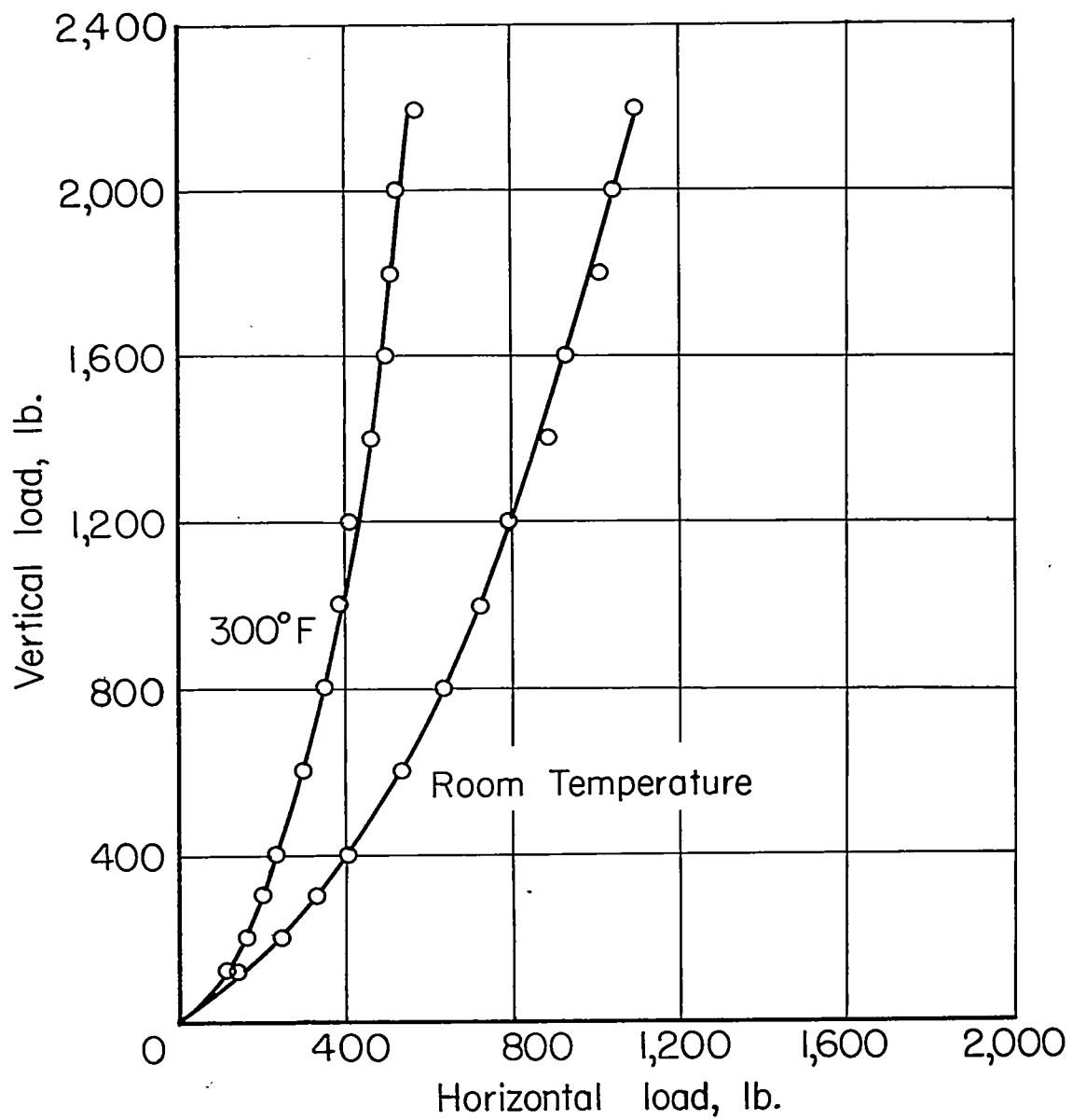
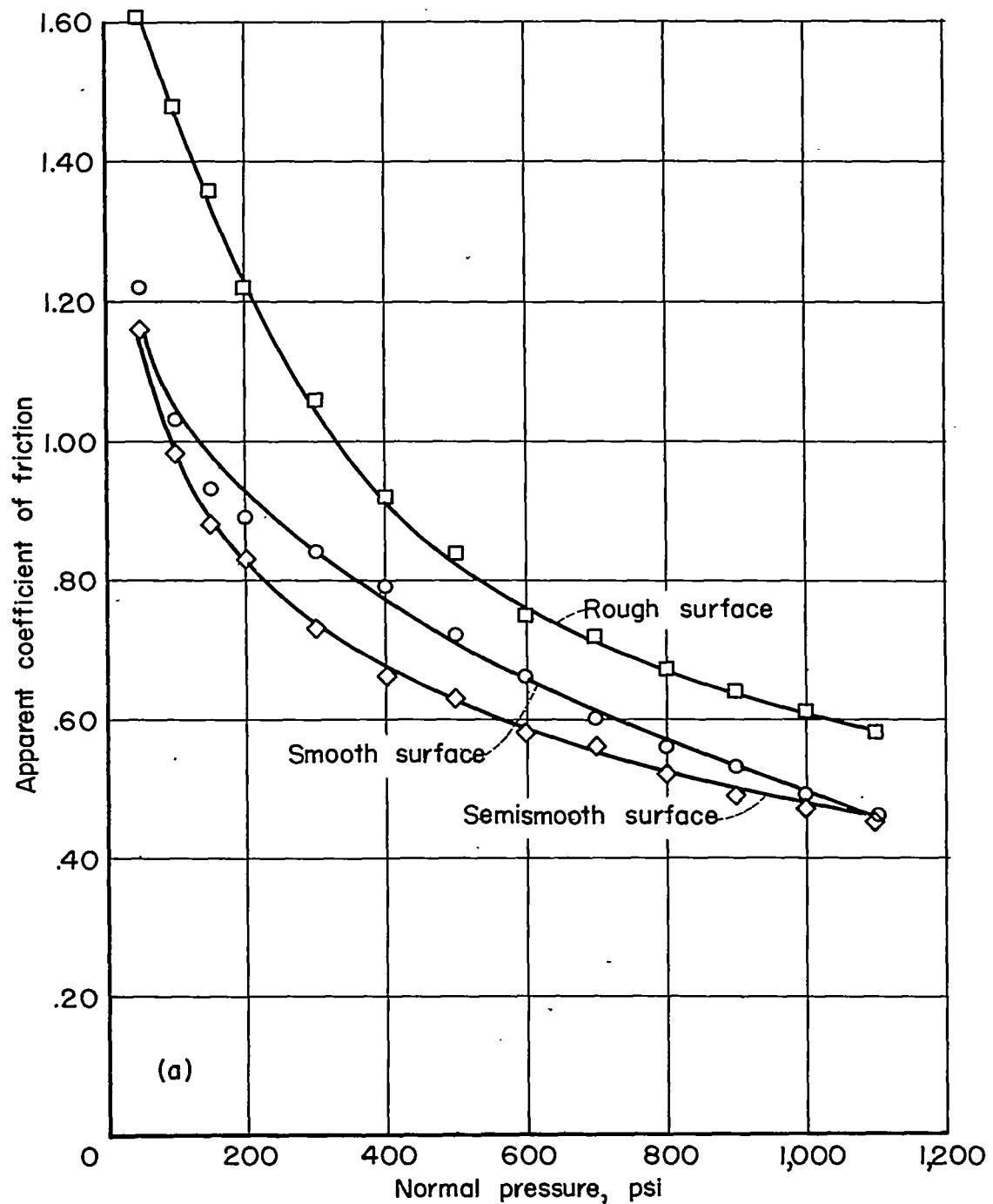
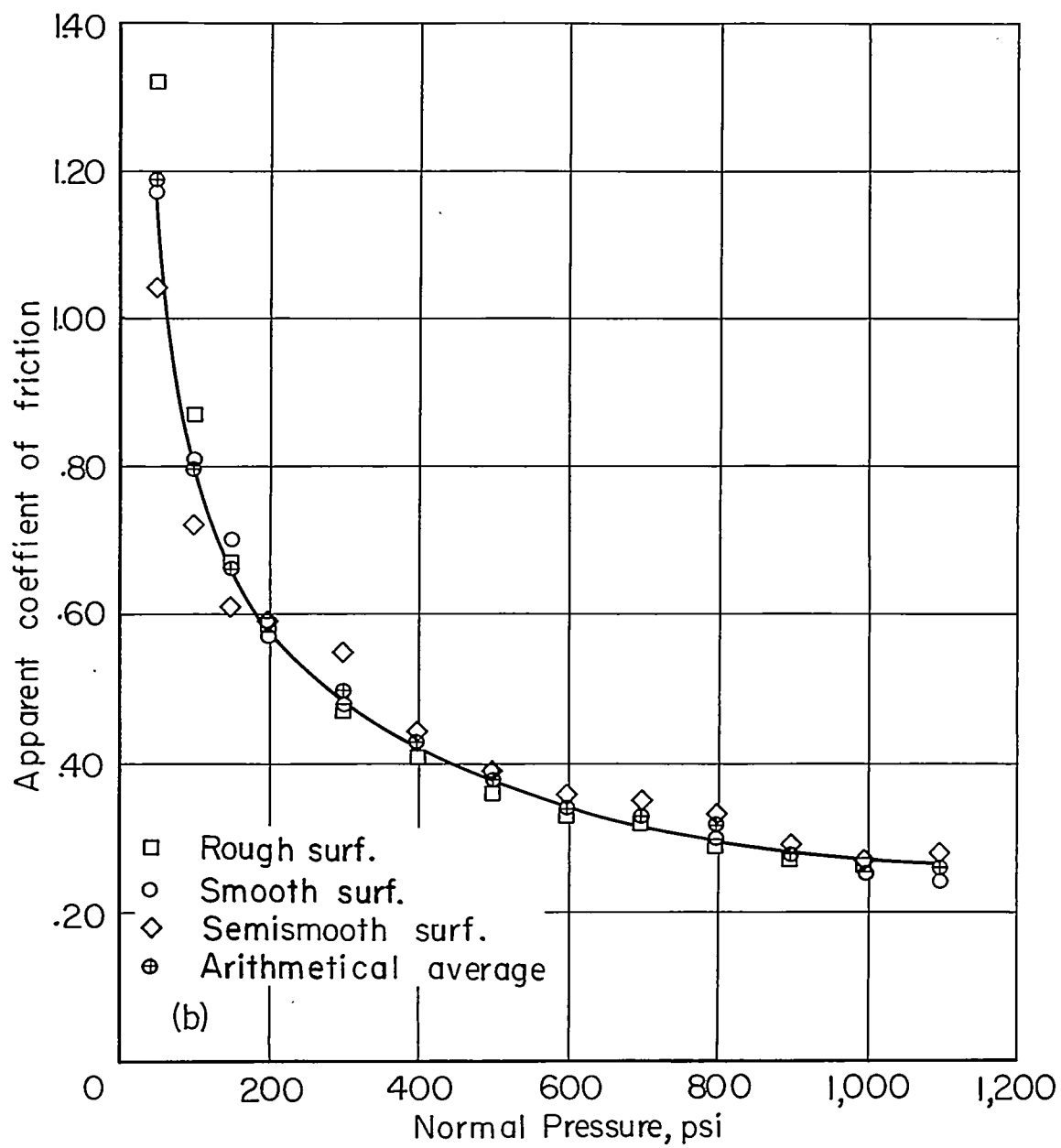


Figure 8.- Vertical load versus horizontal load for high-normal-load tests.
Averaged results for all surfaces.



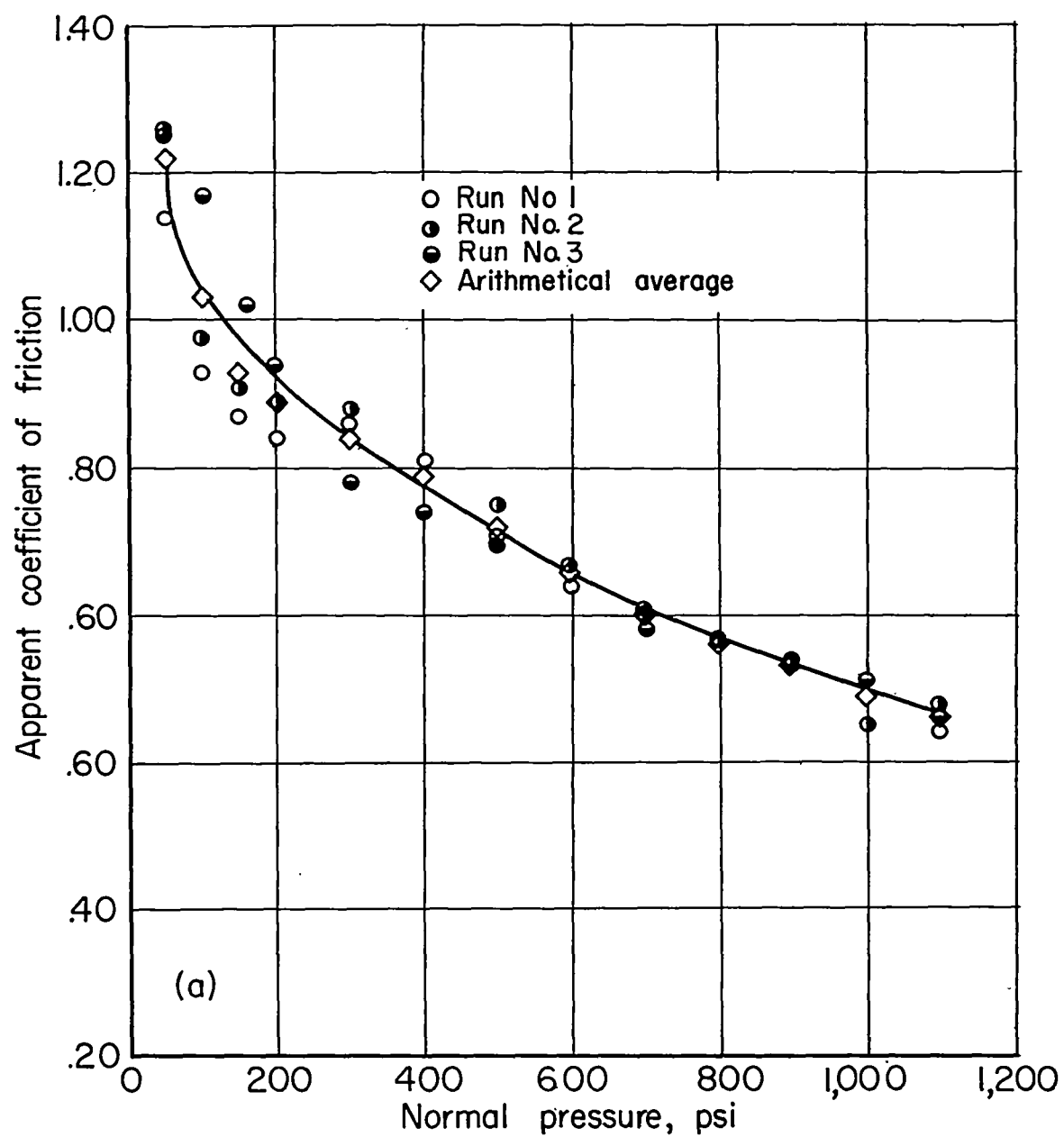
(a) Room temperature. No suitable explanation can be made for smooth-surface curve appearing between semismooth- and rough-surface curves. Values were checked and no errors were found.

Figure 9.- Apparent coefficient of friction versus normal pressure for high-normal-load tests at room temperature and 300° F. Averaged results for all surfaces.



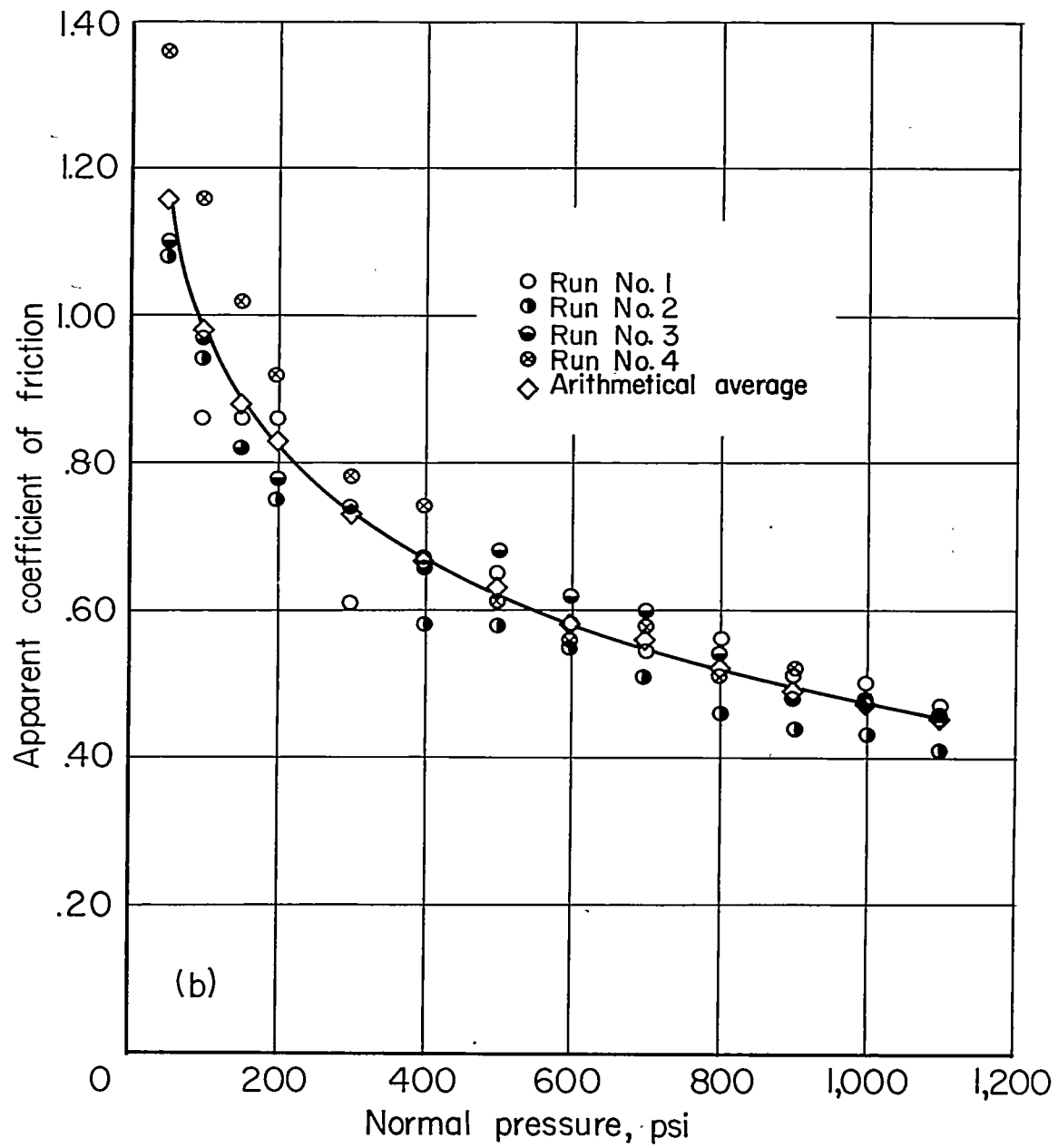
(b) 300° F.

Figure 9.- Concluded.



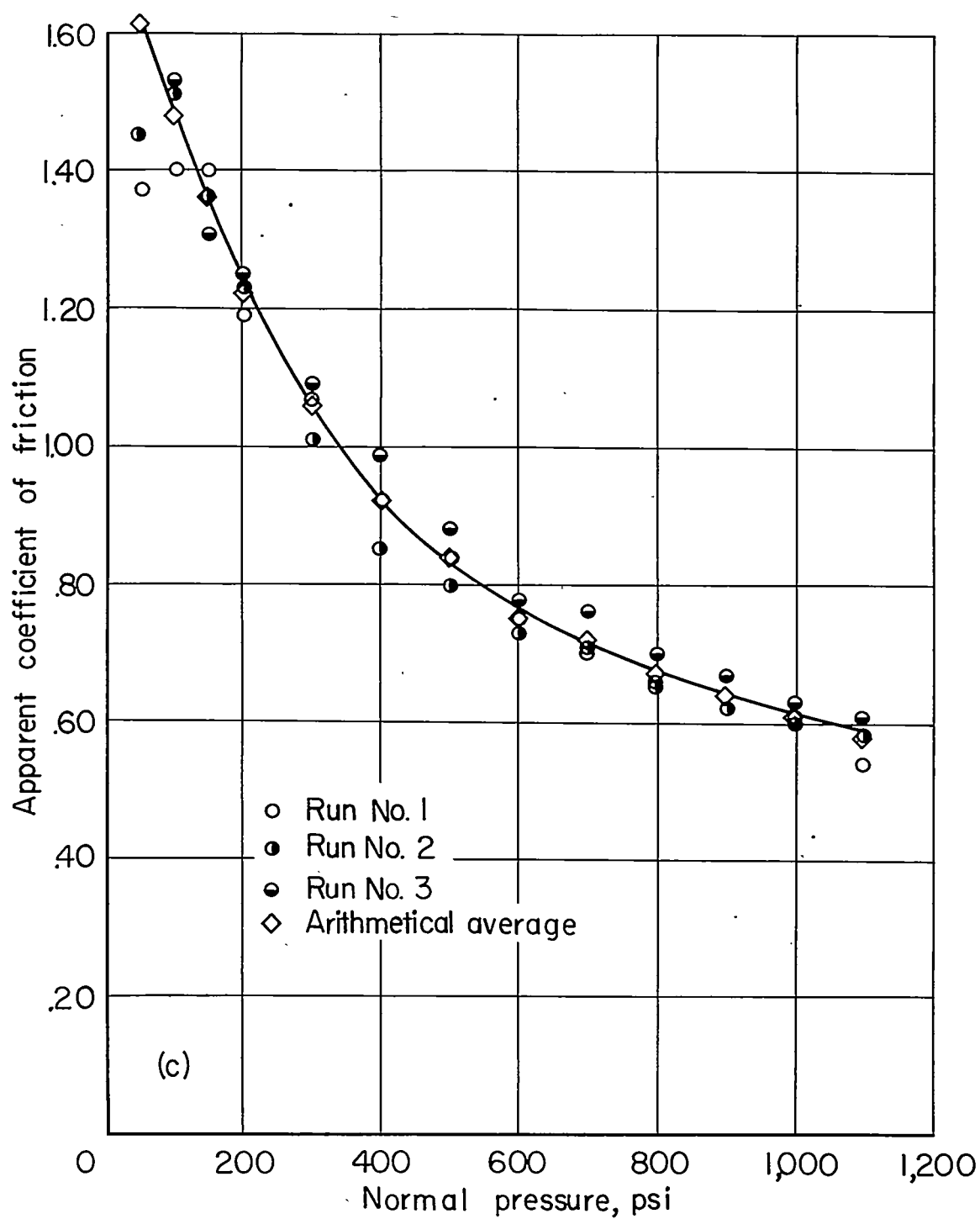
(a) Smooth (troweled) surface.

Figure 10.- Apparent coefficient of friction versus normal pressure for high-normal-load tests of all surfaces at room temperature.



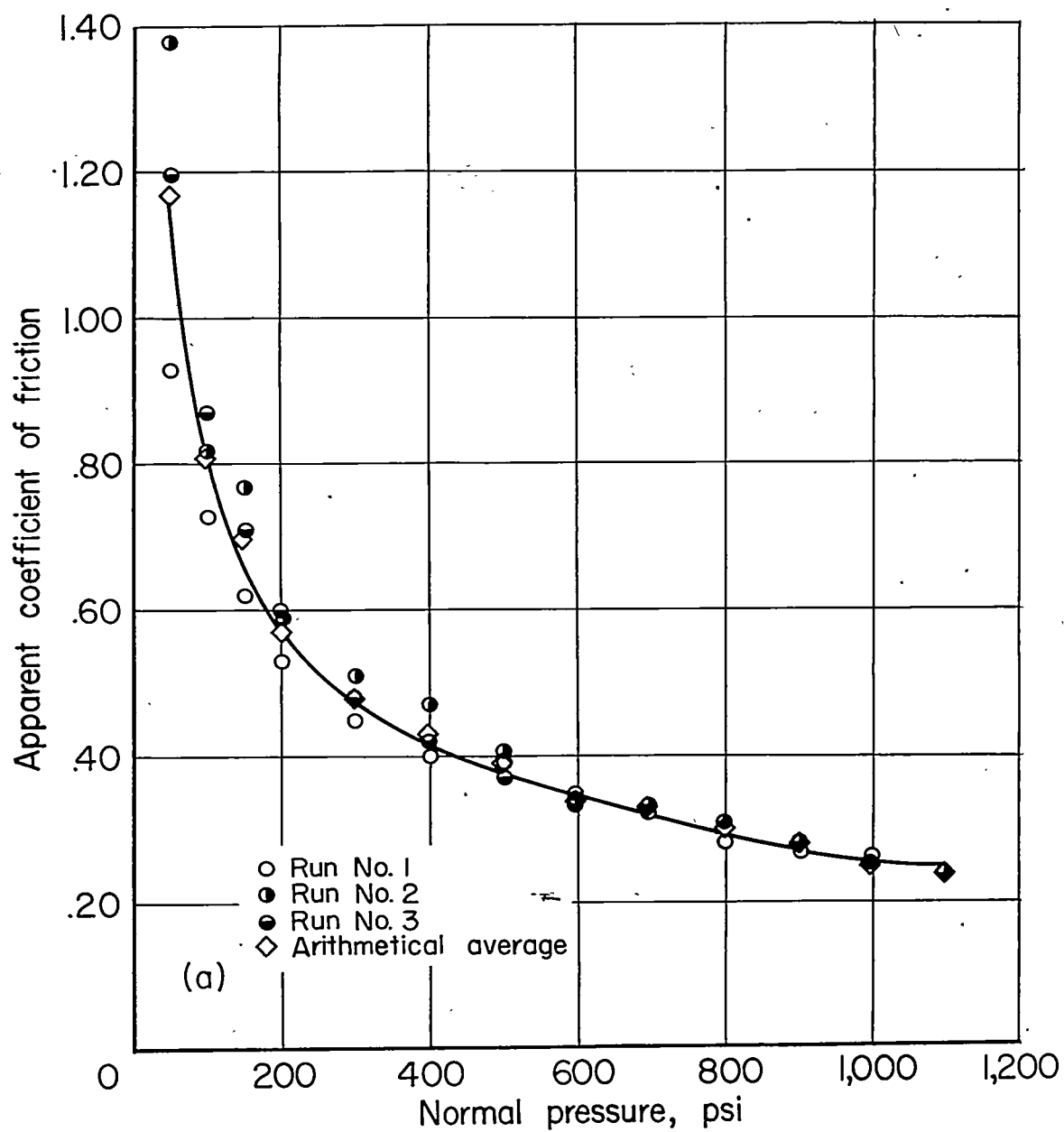
(b) Semismooth surface.

Figure 10.- Continued.



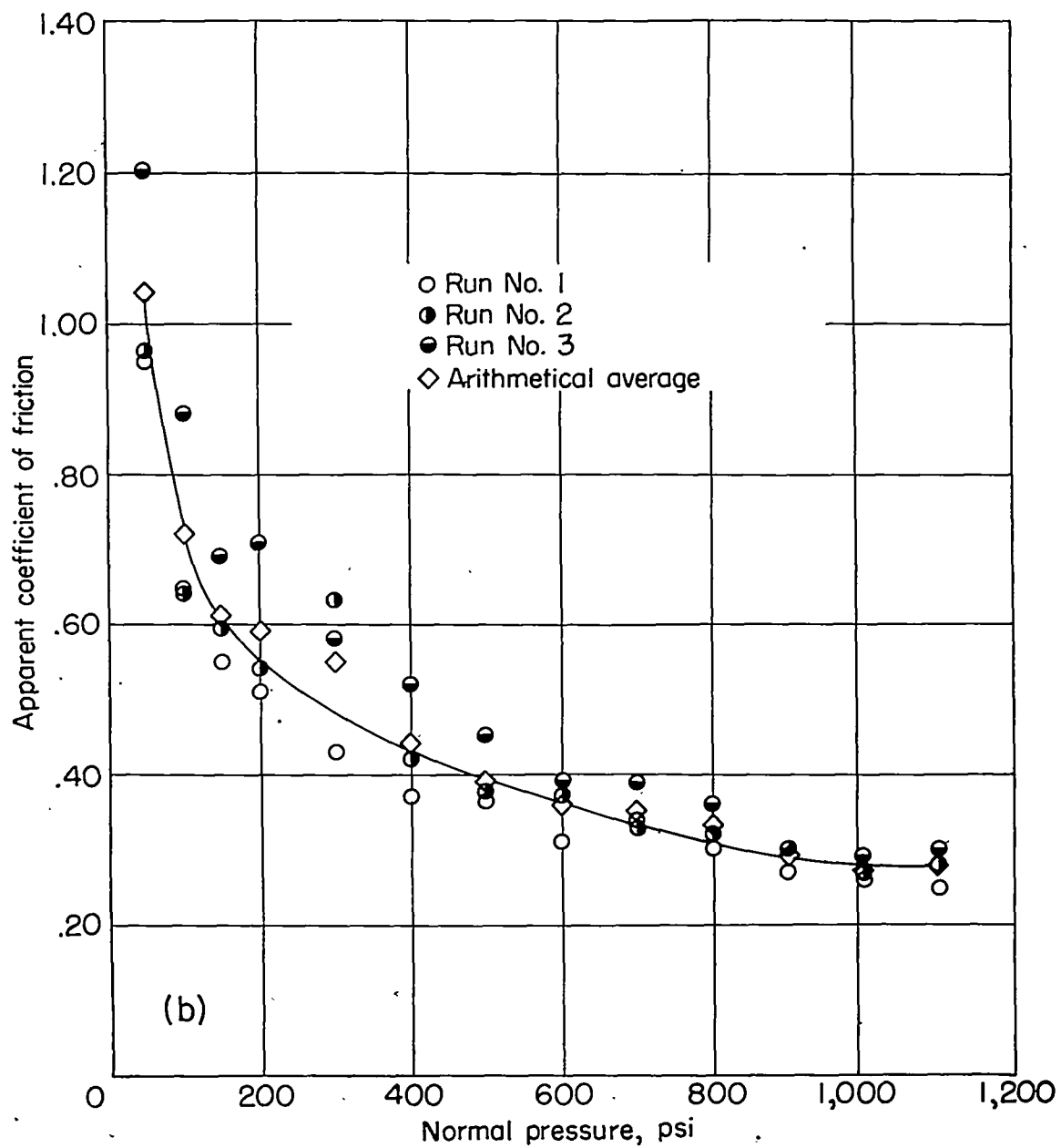
(c) Rough (broomed) surface.

Figure 10.- Concluded.



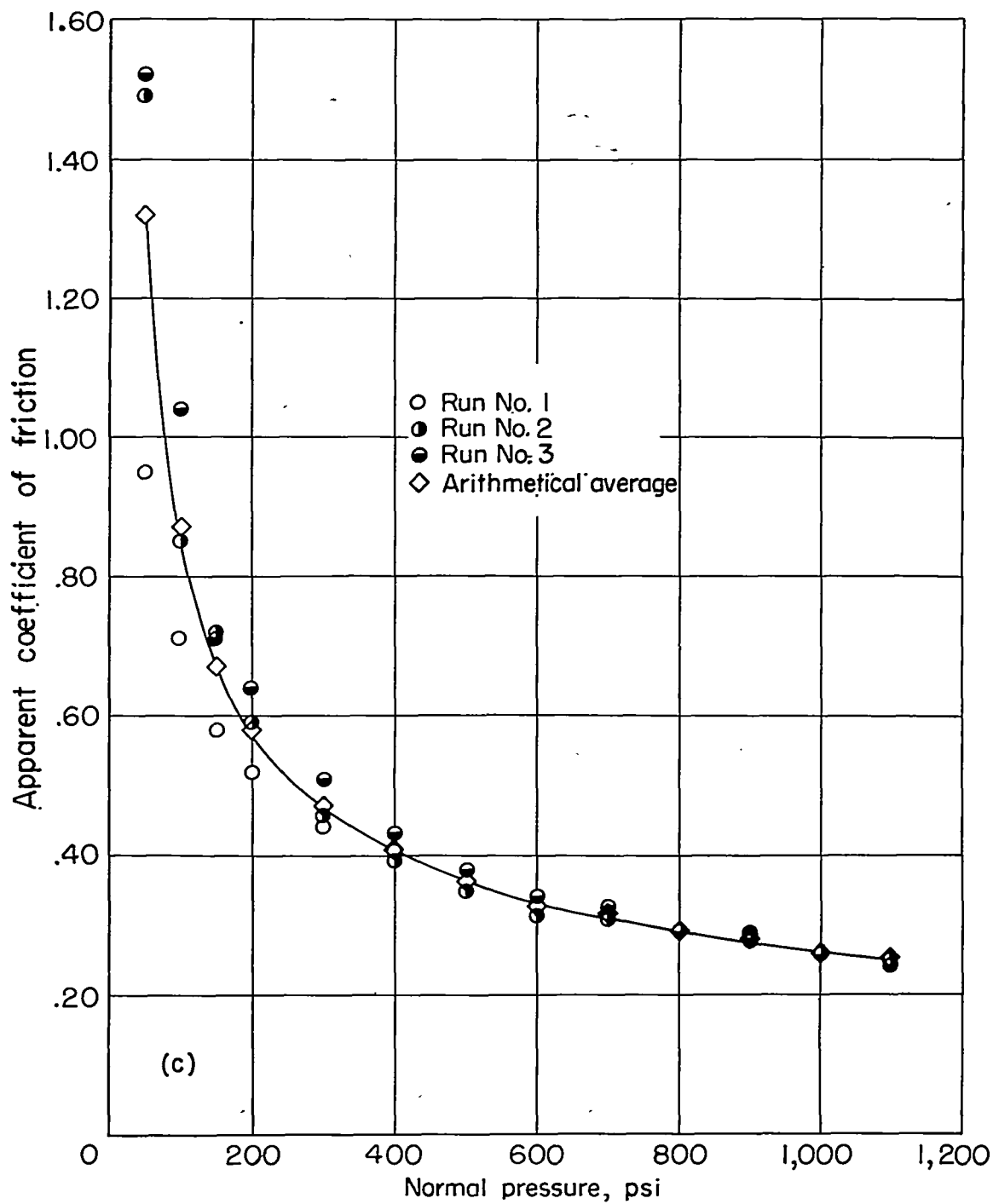
(a) Smooth (troweled) surface.

Figure 11.- Apparent coefficient of friction versus normal pressure for high-normal-load tests of all surfaces at 300° F.



(b) Semismooth surface.

Figure 11.- Continued.



(c) Rough (broomed) surface.

Figure 11.- Concluded.

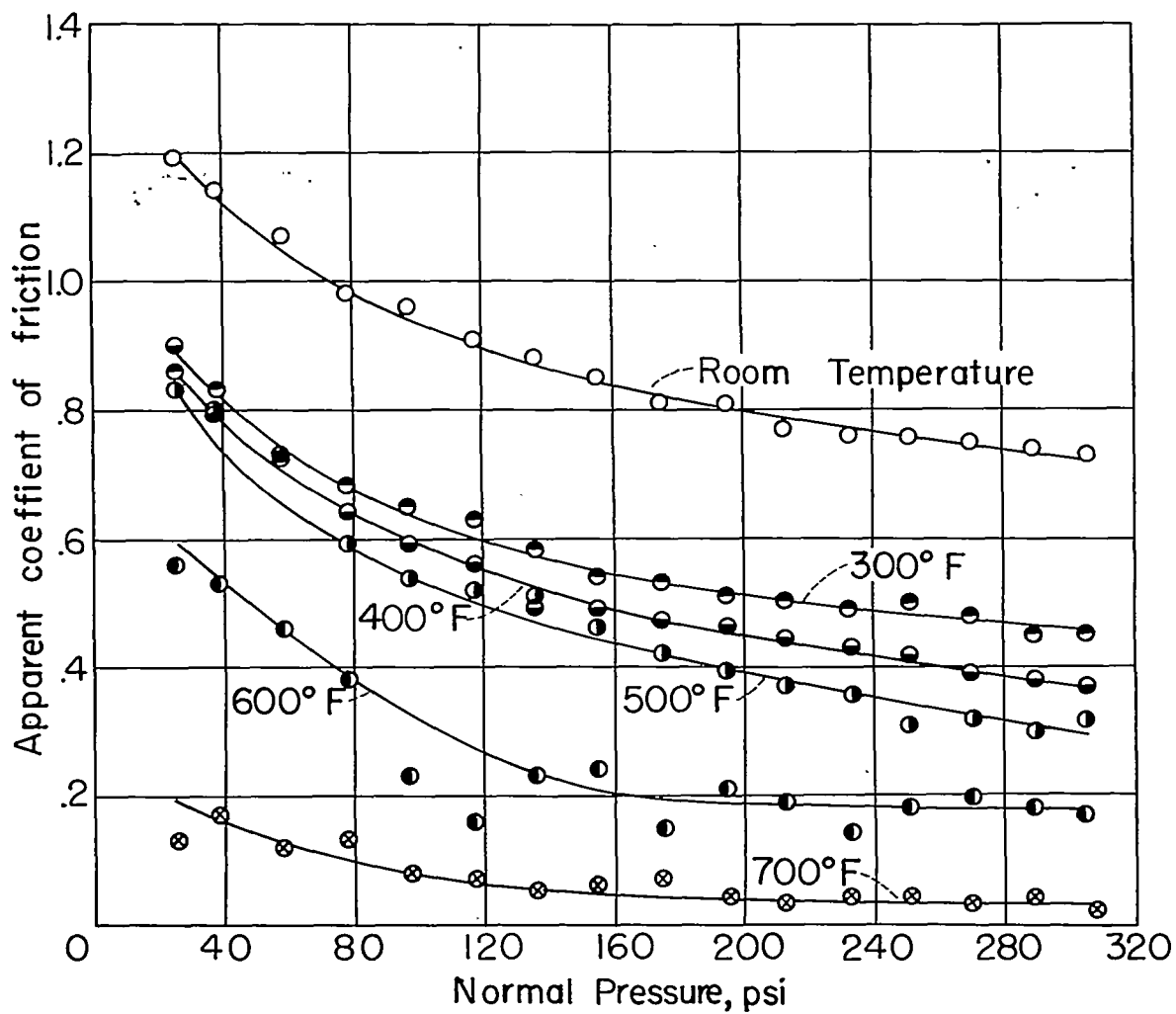


Figure 12.- Apparent coefficient of friction versus normal pressure for low-normal-load tests. Averaged results for all surfaces. All values are arithmetical averages.

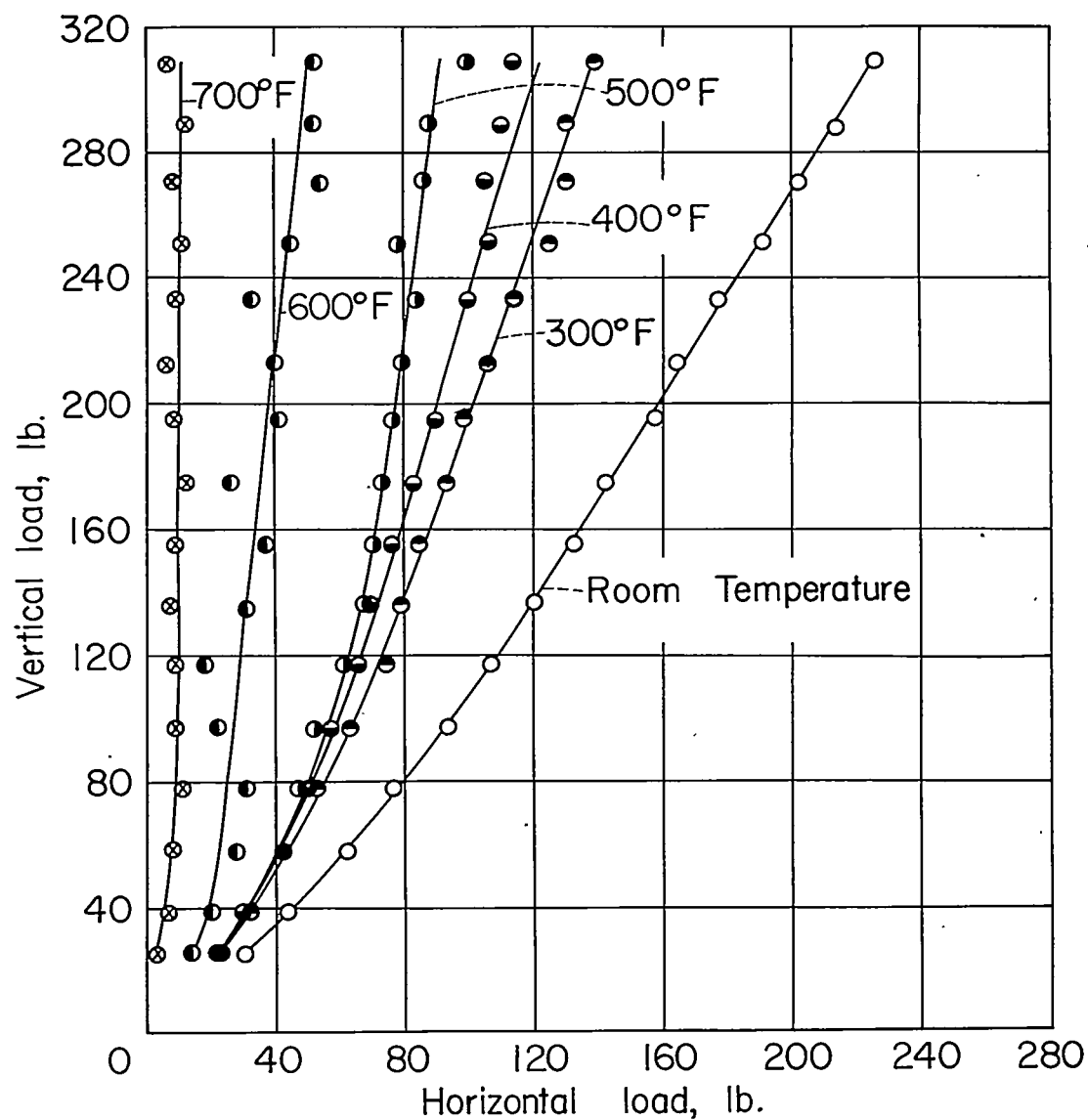
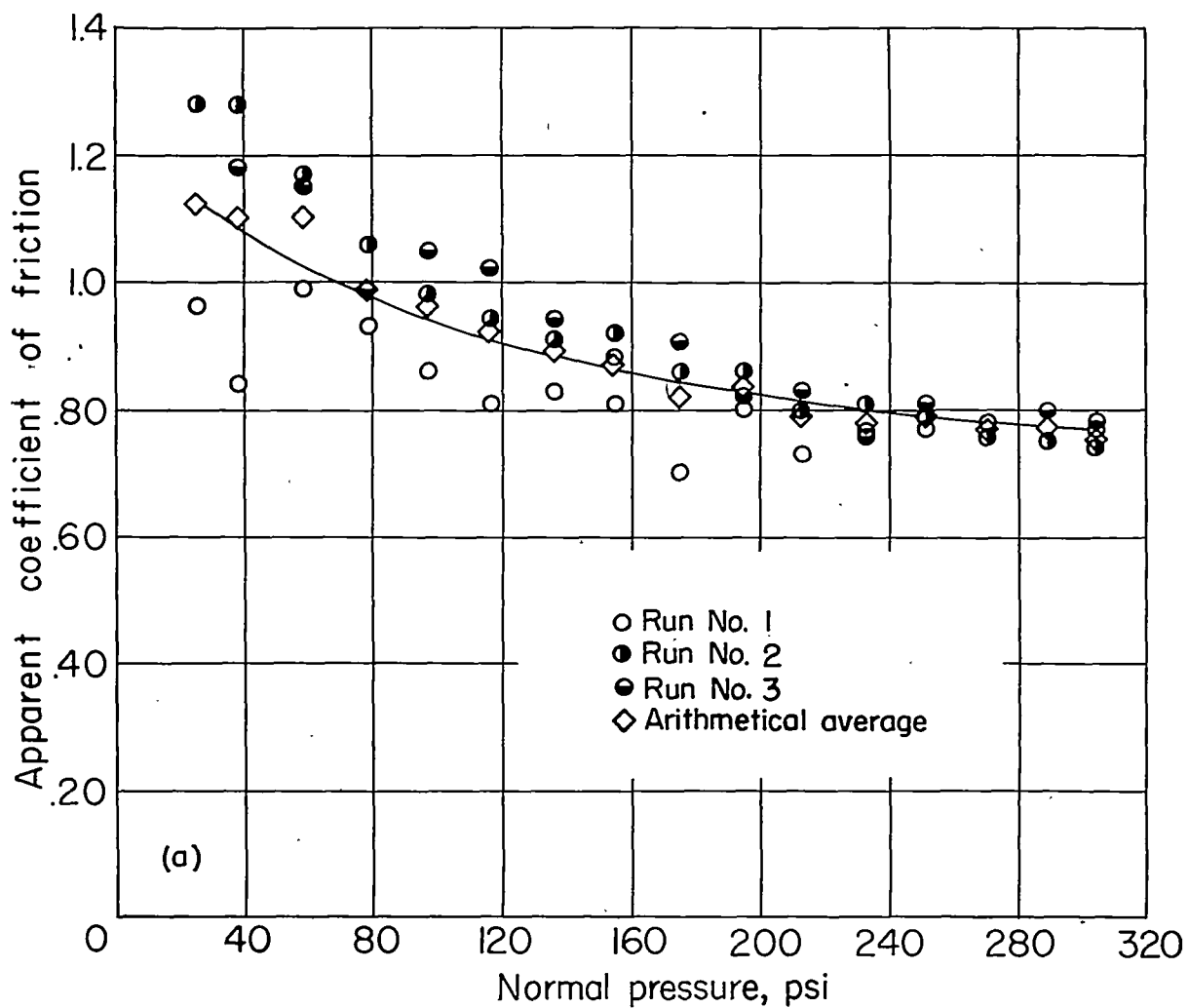
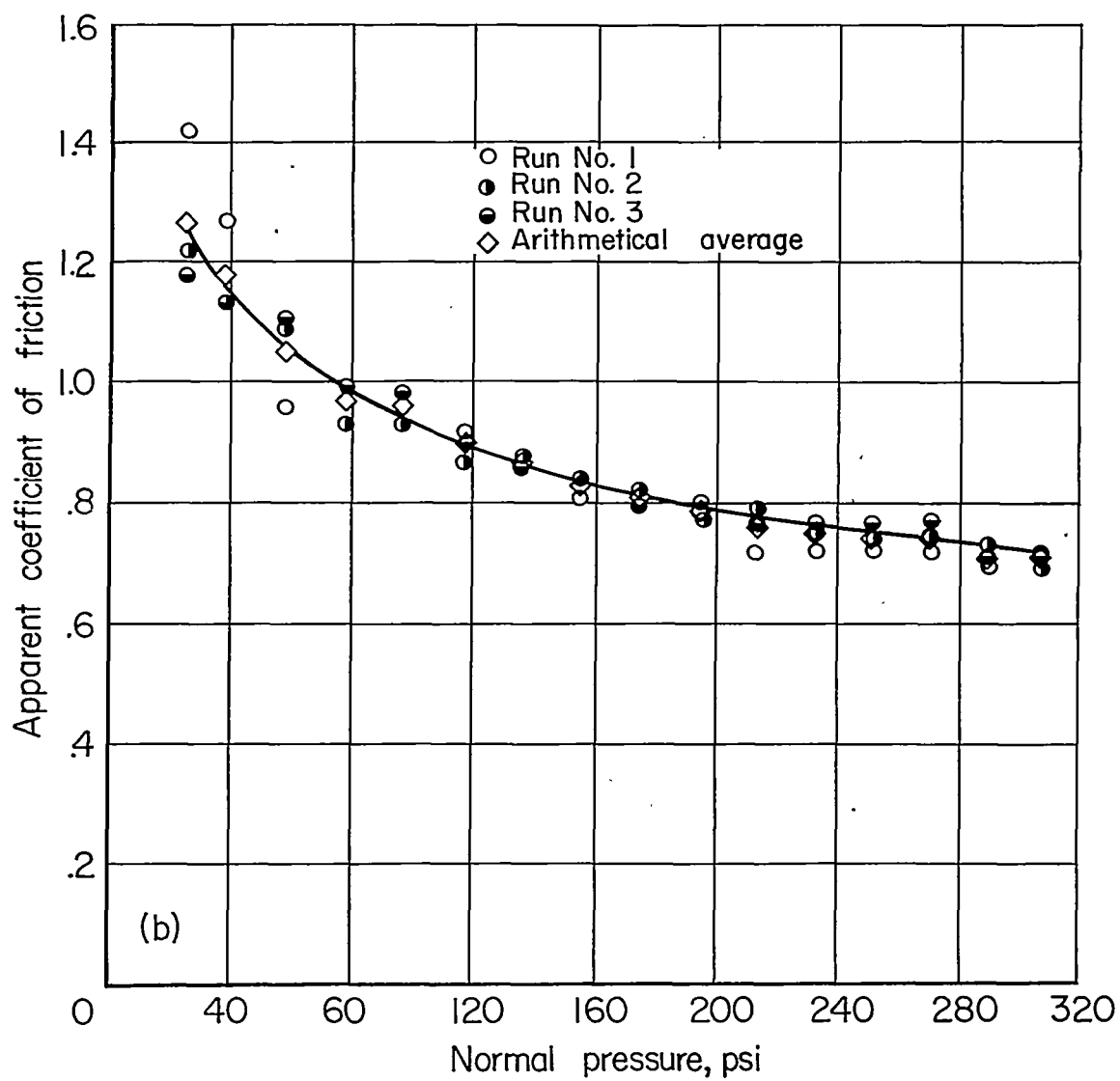


Figure 13.- Vertical load versus horizontal load for low-normal-load tests. Averaged results for all surfaces. All values are arithmetical averages.



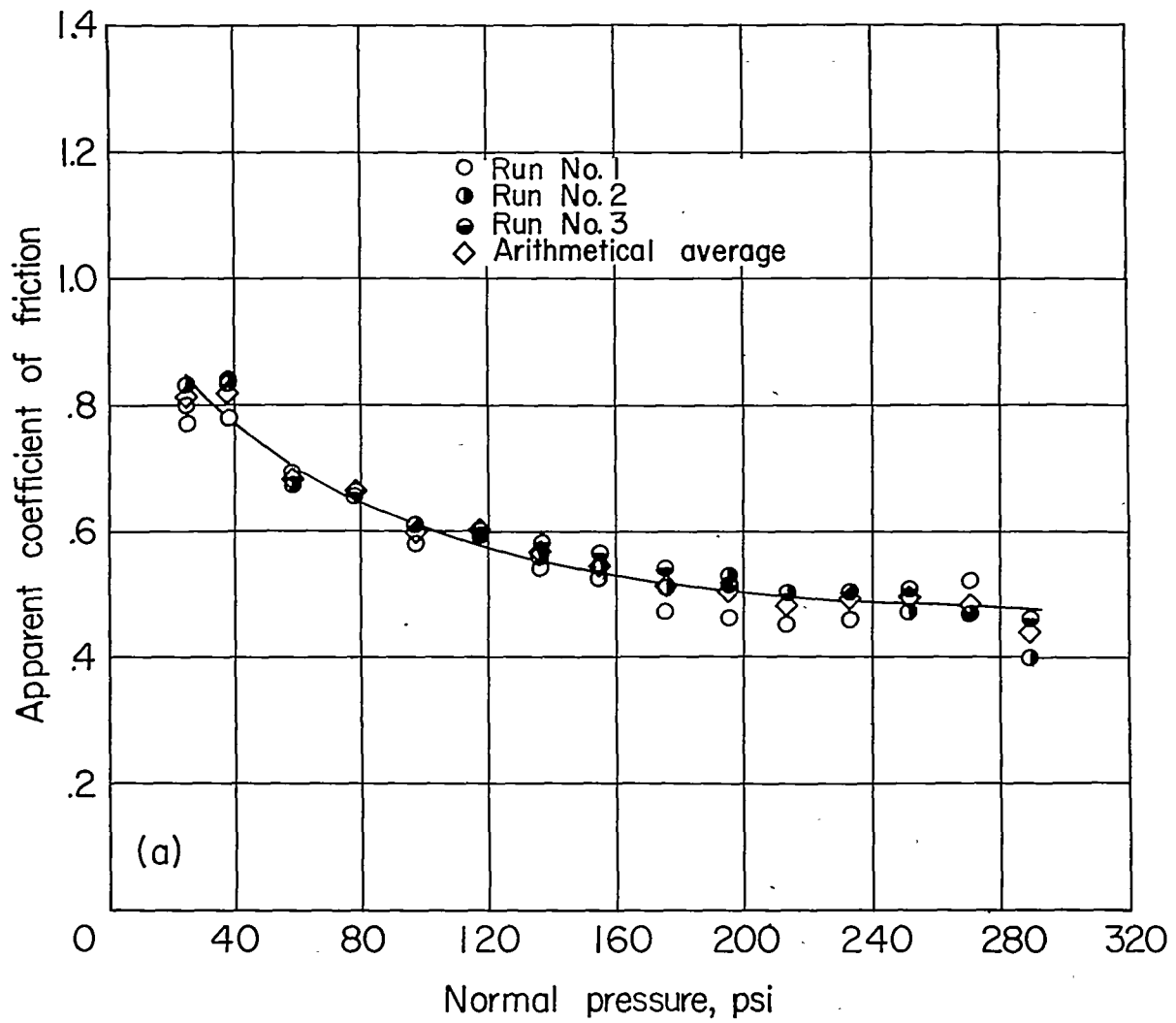
(a) Smooth (troweled) surface.

Figure 14.- Apparent coefficient of friction versus normal pressure for low-normal-load tests at room temperature.



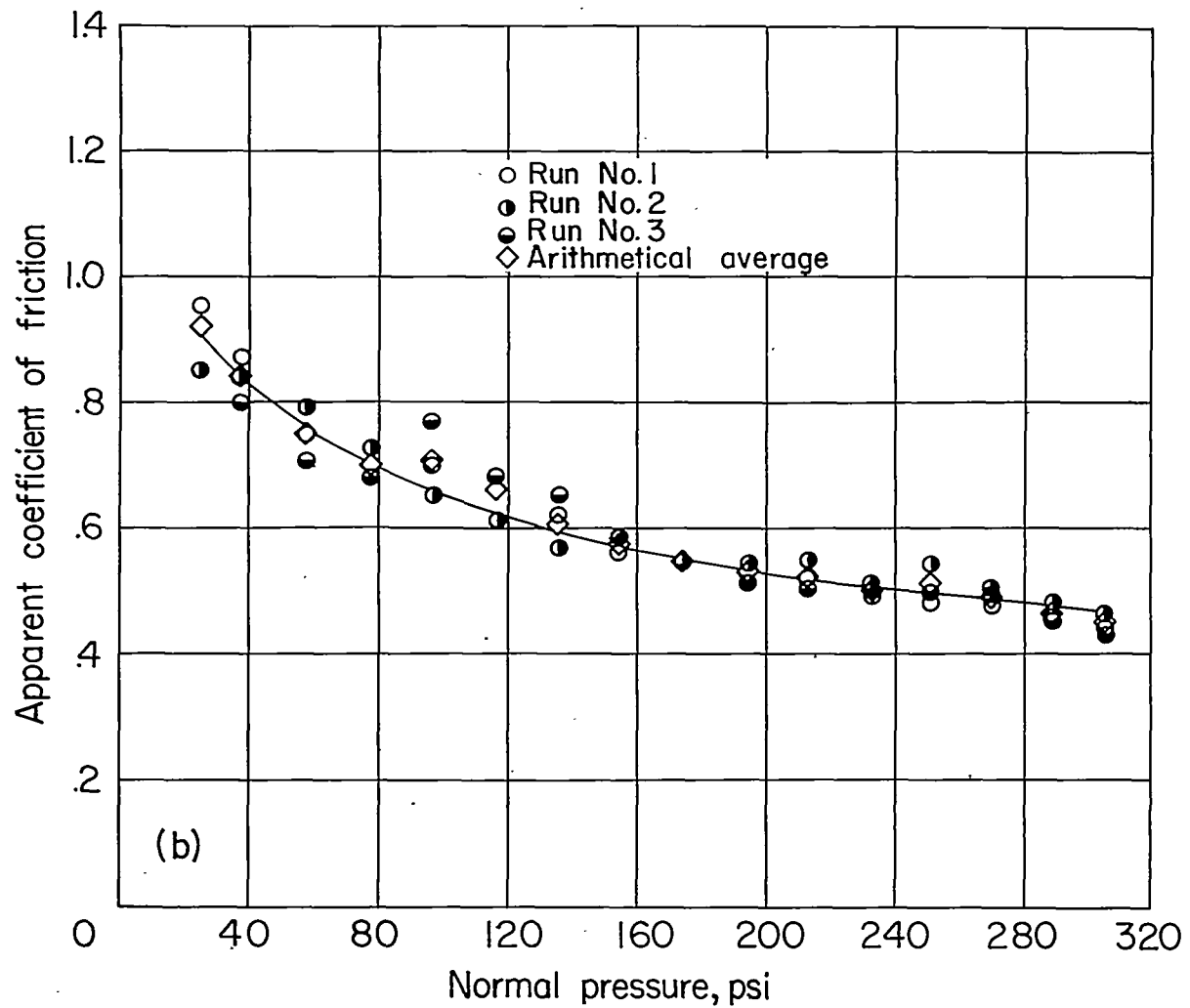
(b) Rough (broomed) surface.

Figure 14.- Concluded.



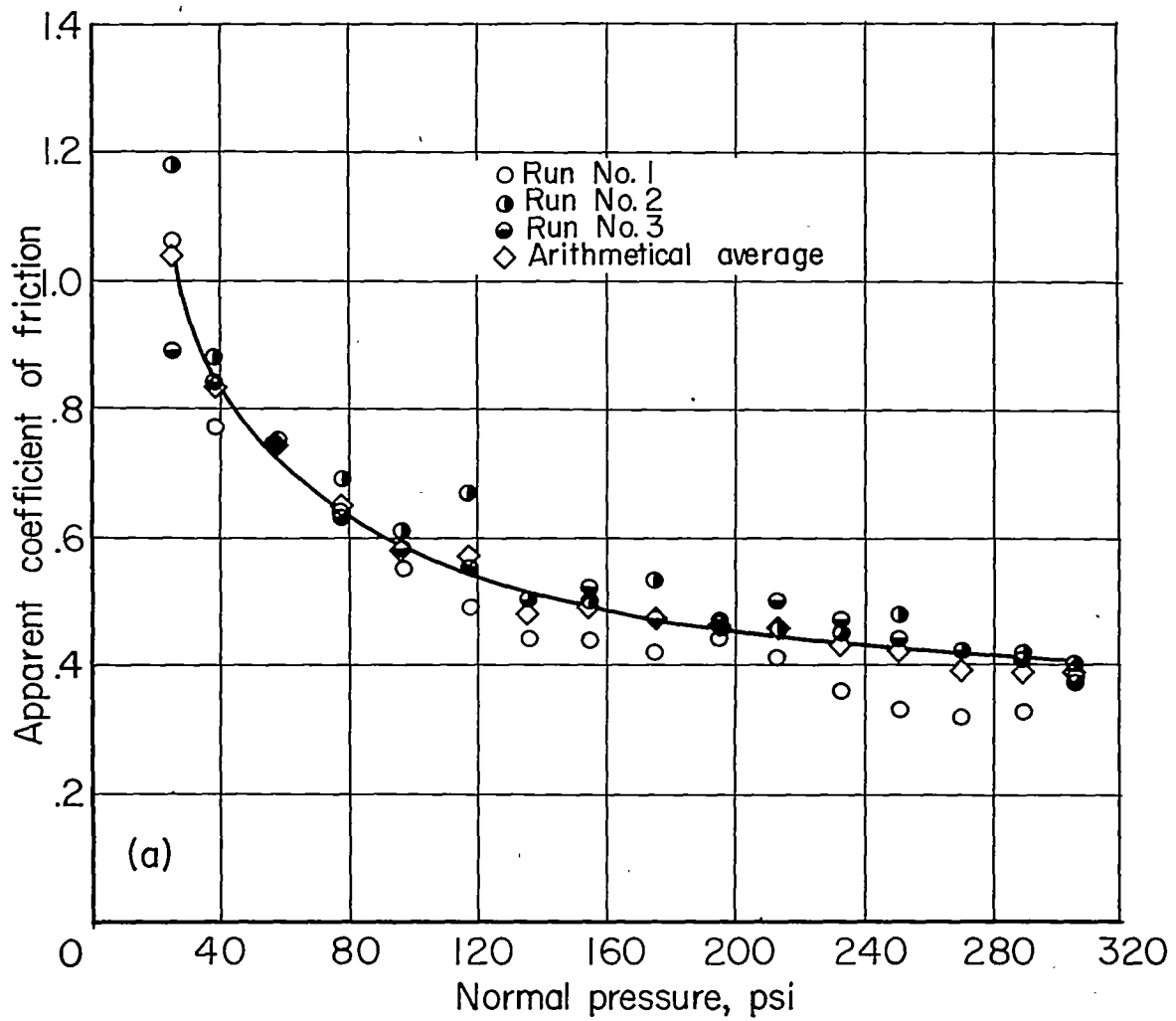
(a) Smooth (troweled) surface.

Figure 15.- Apparent coefficient of friction versus normal pressure for low-normal-load tests at 300° F.



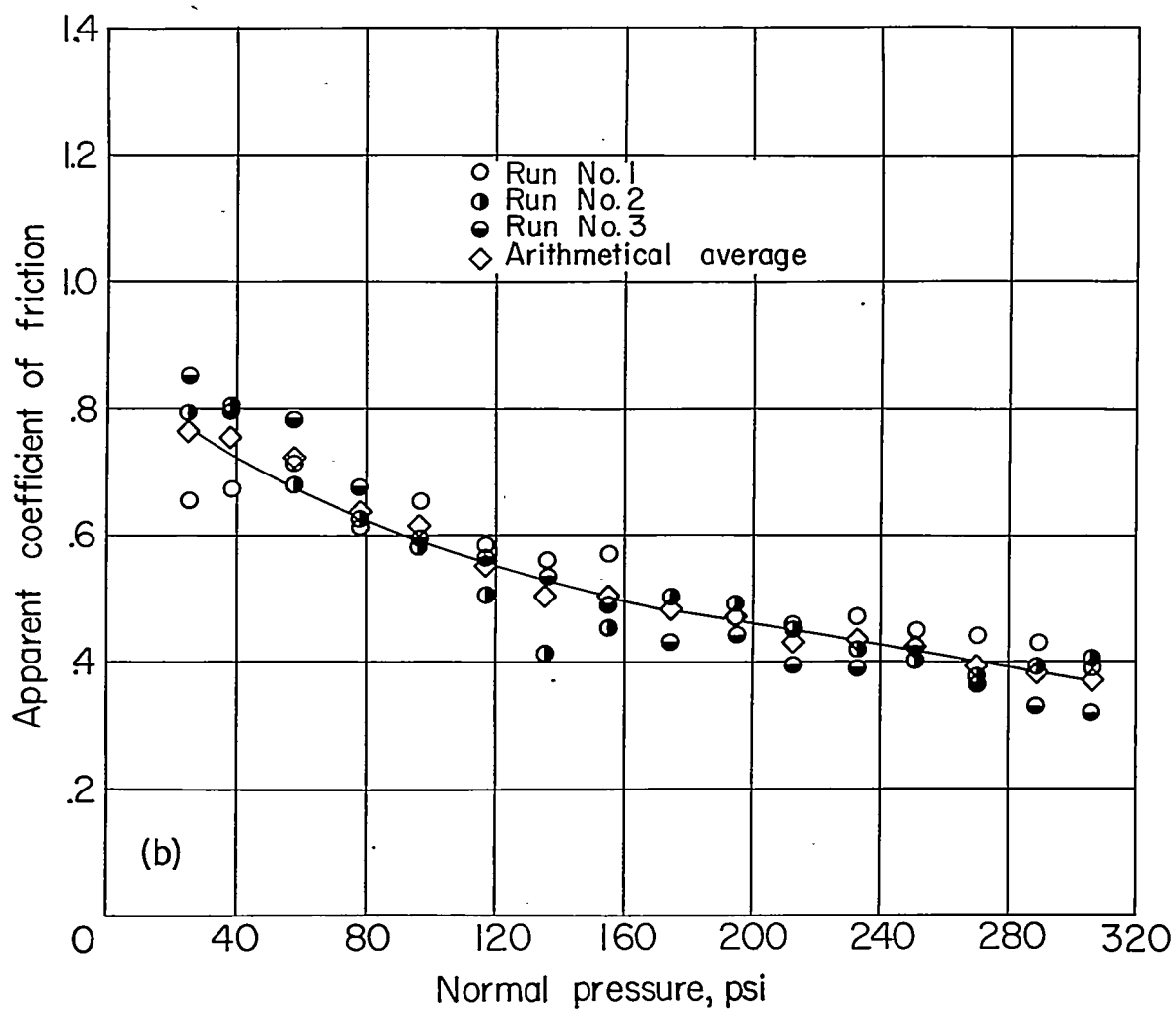
(b) Rough (broomed) surface.

Figure 15.- Concluded.



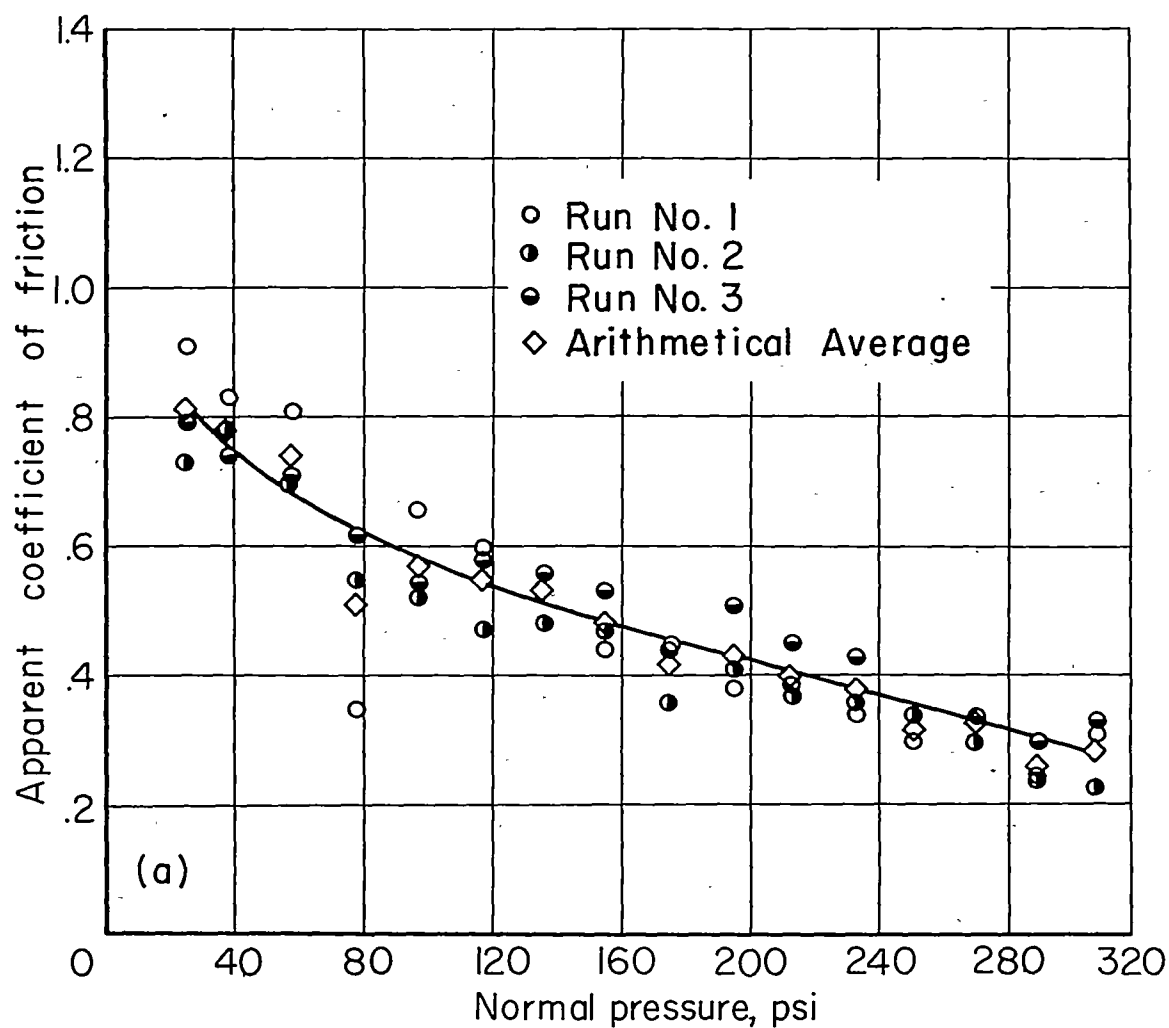
(a) Smooth (troweled) surface.

Figure 16.- Apparent coefficient of friction versus normal pressure for low-normal-load tests at 400° F.



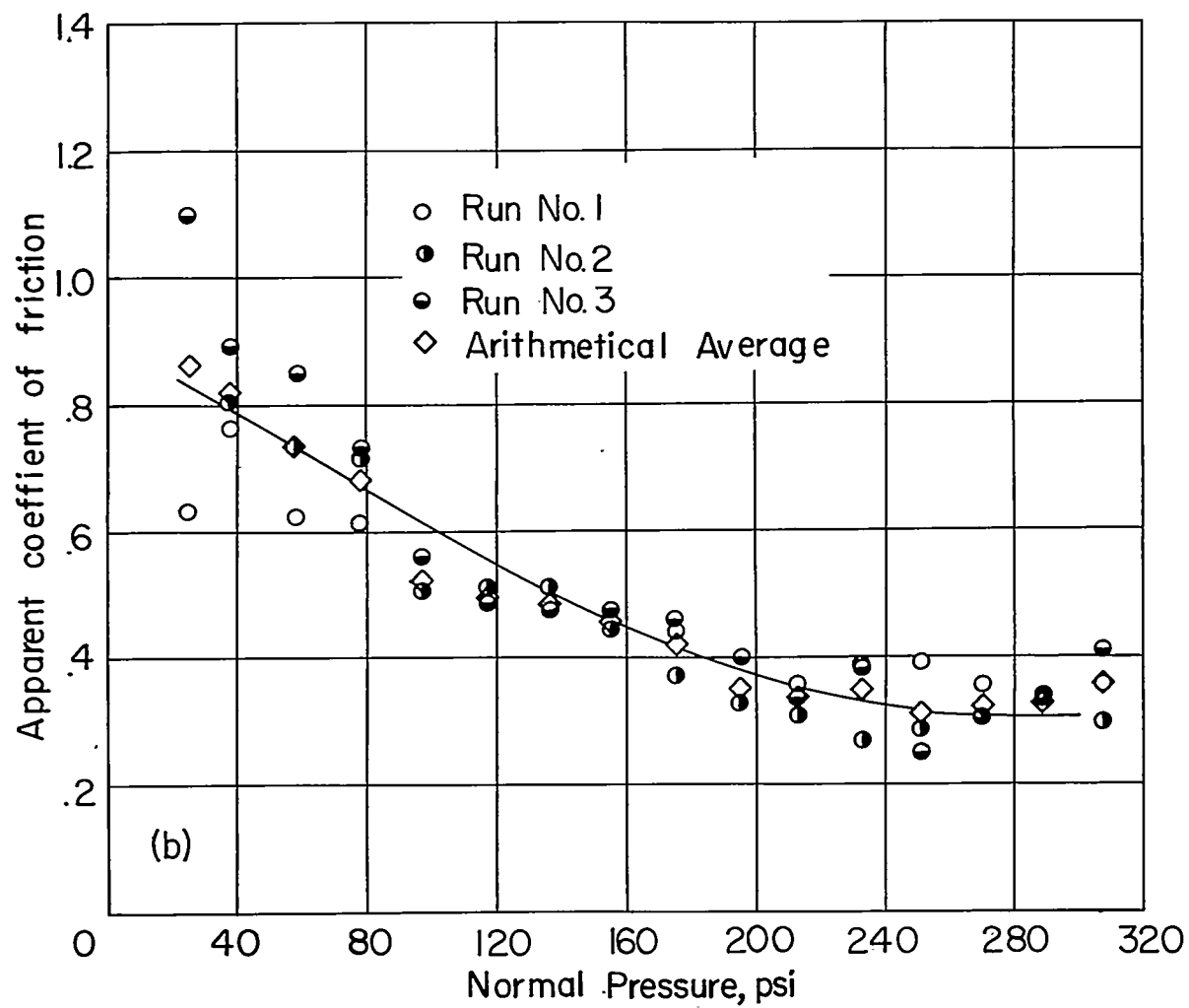
(b) Rough (broomed) surface.

Figure 16.- Concluded.



(a) Smooth (troweled) surface.

Figure 17.- Apparent coefficient of friction versus normal pressure for low-normal-load tests at 500° F.



(b) Rough (broomed) surface.

Figure 17.- Concluded.

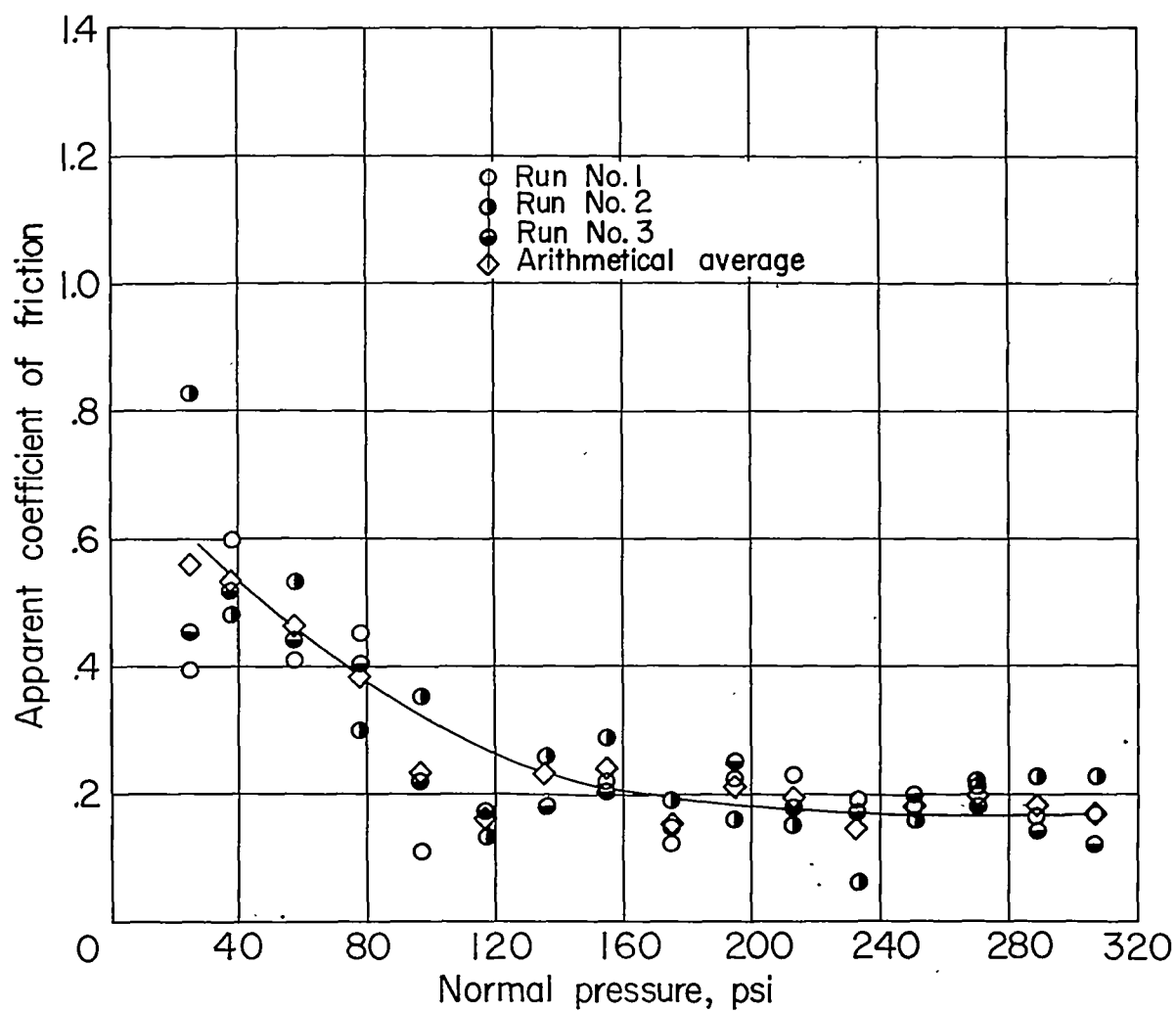


Figure 18.- Apparent coefficient of friction versus normal pressure for low-normal-load tests at 600° F. Smooth surface.

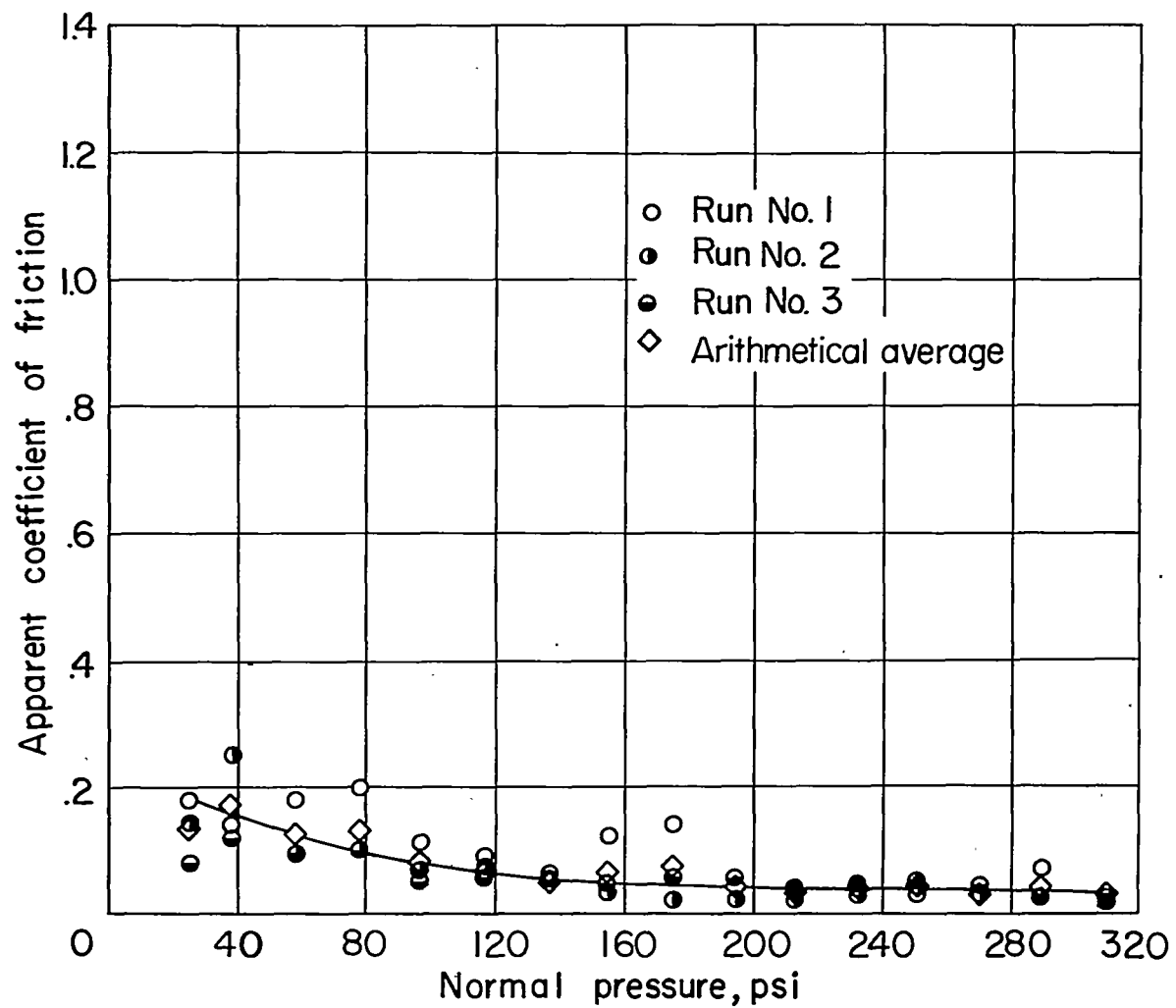


Figure 19.- Apparent coefficient of friction versus normal pressure for low-normal-load tests at 700° F. Smooth surface.

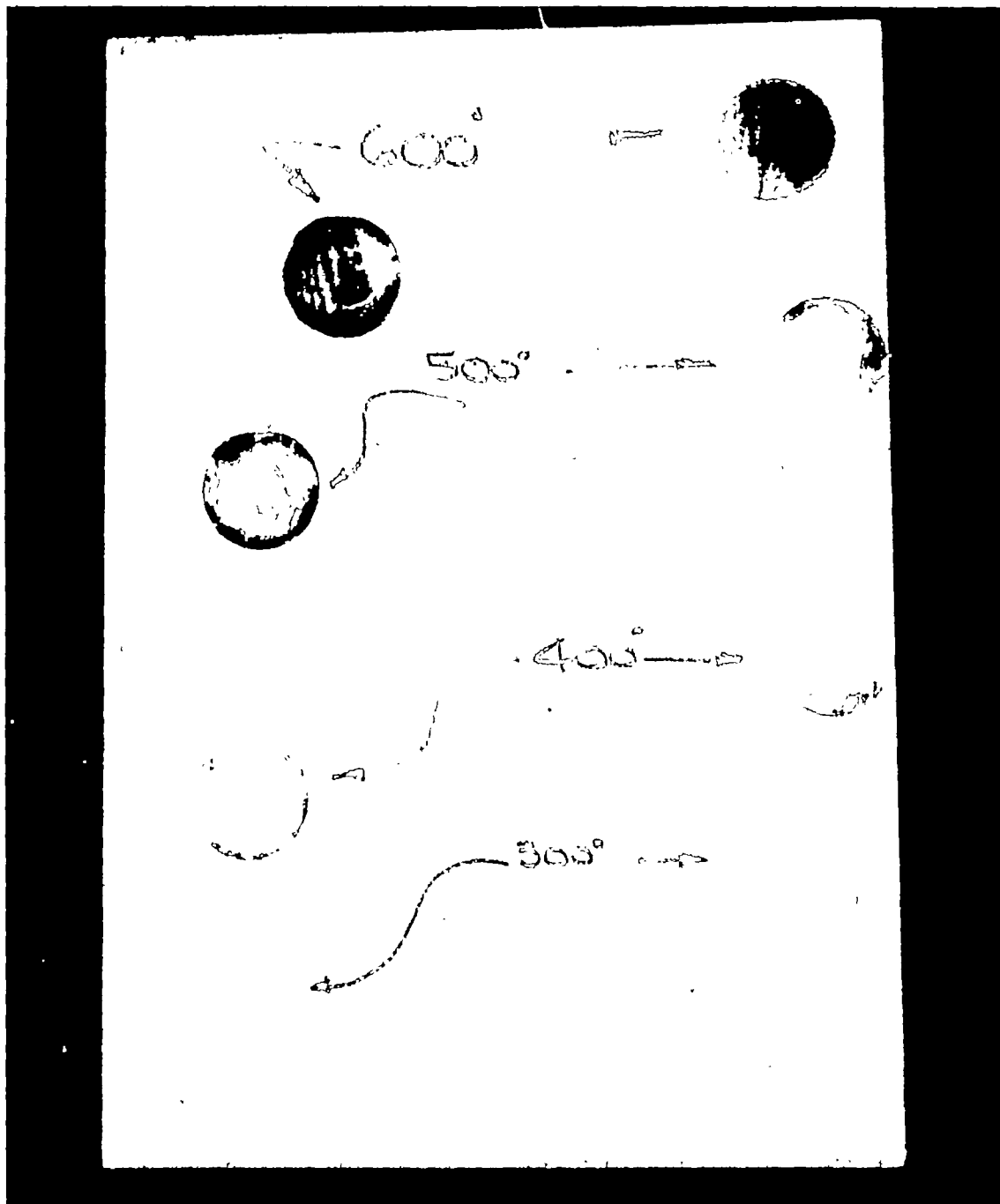


Figure 20.- Rubber printing at various temperatures. L-87980

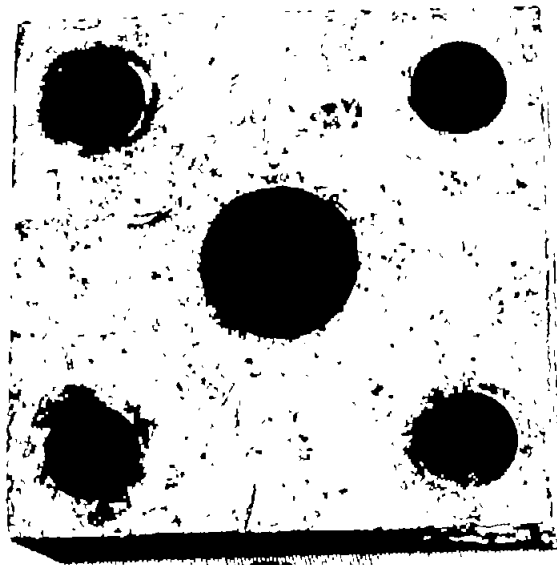


Figure 21.- Mounting block and typical tested specimens. L-87981